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XSM-65 SERIES B & C

PROPULSION SYSTEM FAMILIARIZATION MANUAL

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CONVAIR DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO, CALIFORNIA

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FOREWORD

This manual contains descriptive, operational, servicing, and maintenance information on the XSM-65B and C Missile Propulsion System. Its purpose is to provide sufficient information to permit operation and maintenance of the propulsion system in the field. When detailed information beyond the scope of this document is required, references will be made to the various supporting drawings and handbooks currently in existence. A listing of the applicable Rocketdyne and Convair handbooks and drawings to which reference may be made will be found in Section 8.

The information in this handbook applies to the XSM-65 Series B and C missiles, serial numbers 1B through 13B, and 1C through 14C.

The technical information contained in this manual was correct at the date of publication. Future versions of this manual will reflect information required to bring it up to date and to present all new material affecting improvement of operation and maintenance techniques.

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1.0 DESCRIPTION OF THE PROPULSION SYSTEM

1.1 GENERAL

The XSM-65 Series B Missile Propulsion System may be divided into two sections, the Missileborne System and the Ground Support System. The missileborne system consists basically of the rocket engines necessary to propel and control the missile in flight, together with the various disconnect fittings required for servicing and starting the rocket engines prior to flight. The ground support system consists of launcher equipment required for servicing the missile with propellants, transfer units for filling the missile with fuel and oxidizer, and control systems required for servicing, starting, and controlling the rocket engines prior to launching.

The Atlas cluster rocket engine is made up of three subengine assemblies: an XLR89-NA-1 booster rocket engine, an XLR105-NA-1 sustainer rocket engine, and two XLR101-NA-1 vernier rocket engines. These assemblies, together with electrical harnesses, interconnect lines, and the necessary start system components, combine to form the MA-1 propulsion system. It consists of dual low-altitude booster thrust chambers, a high-altitude sustainer thrust chamber, and two small vernier thrust chambers which are used for roll control, directional, and velocity trim. The design of the system is such that the various engines can be installed and removed independently of each other.

Each of the rocket engines develops thrust by burning turbopump-fed liquid oxygen and RP-1 propellants. The vernier engines are fed propellants from the sustainer engine turbopump during mainstage, and small pressurized propellant tanks provide starting and solo operation following sustainer cutoff.

Figures 1 and 2 illustrate the general location of the engines on the missile with respect to the missile axis. Identification of the thrust chambers and other major components will always be made in accordance with the numbering shown, and reference will be made to these Figures in the description of major assemblies. Figure 3 is a propulsion system schematic diagram of the XSM-65 Series B missile.

Each thrust chamber attaches to the missile structure by a gimbal assembly which permits freedom of movement for directional control. Since the propulsion system is not designed for variable thrust, the rocket engine performance is demonstrated at specified rated thrust settings. These specification ratings at standard sea level static conditions are listed in Figures 4 and 5.

Supplied as accessories with the engine are a single element heat exchanger in the gas generator exhaust system of the XLR105-NA-1 engine and a dual element heat exchanger in the gas generator exhaust of the XLR89-NA-1 engine. Drives for hydraulic pumps are provided on the XLR105-NA-1 and XLR89-NA-1 turbopump accessory pads.

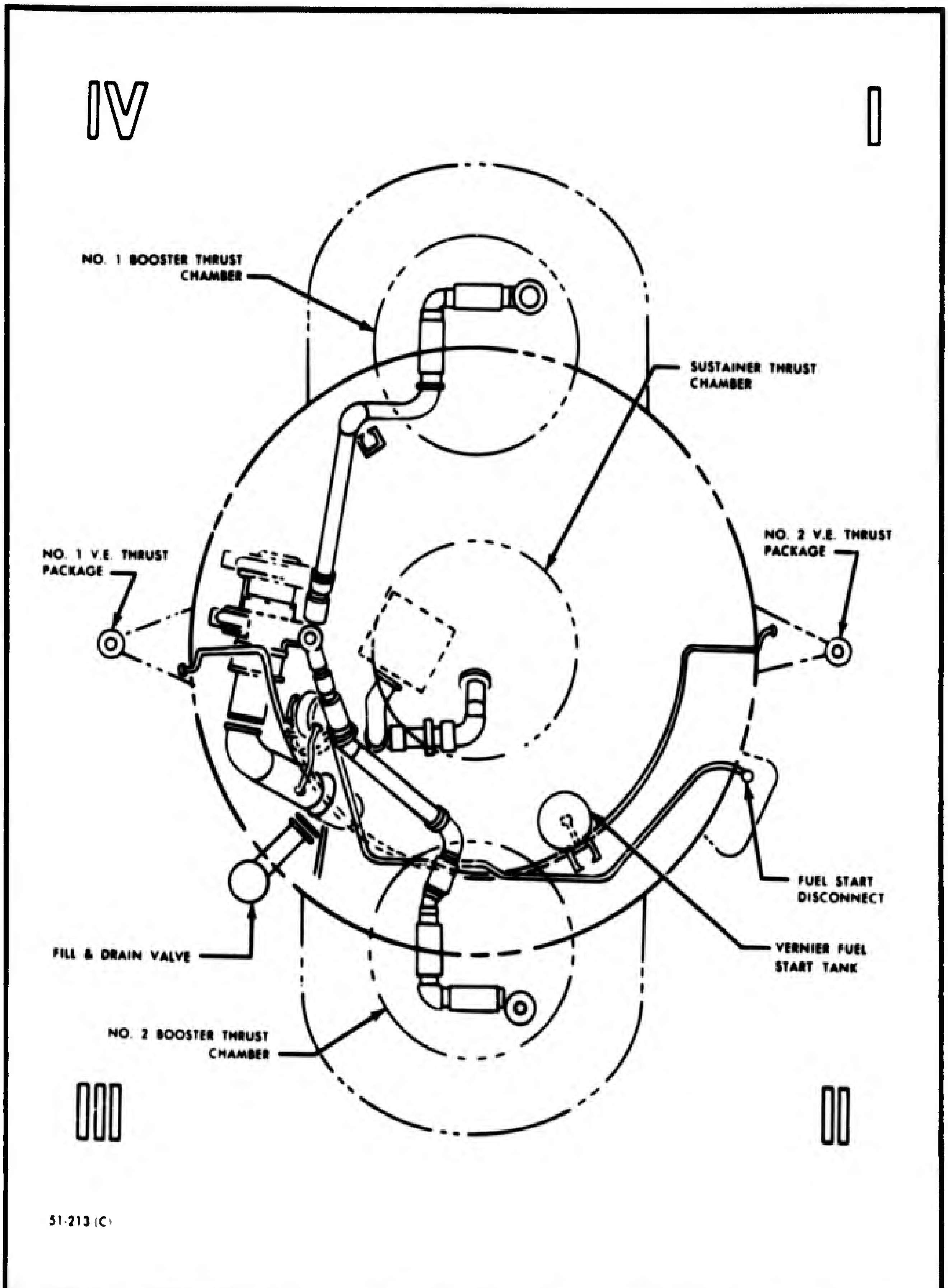


Figure 1. Fuel Supply System, View Looking Forward

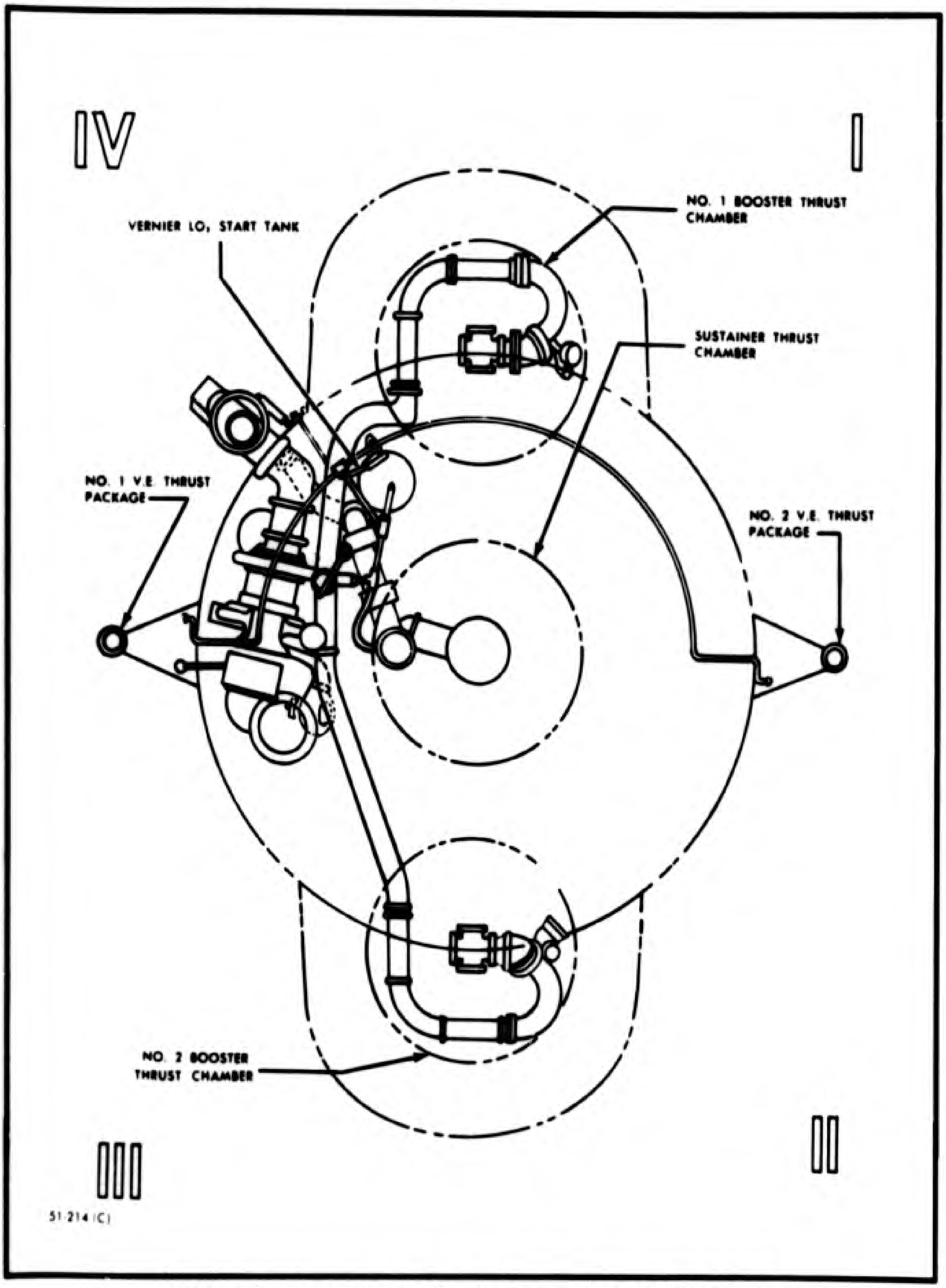
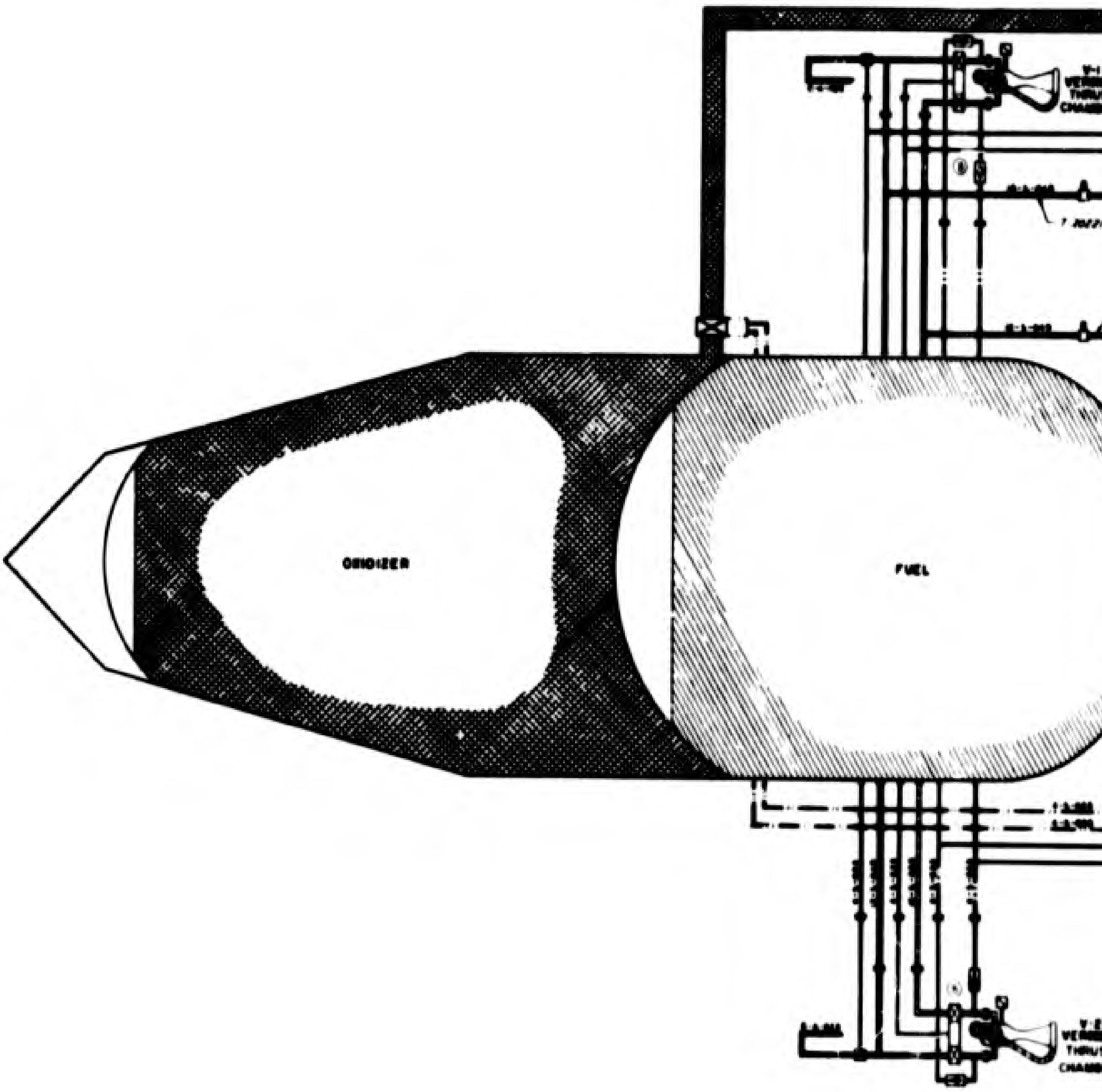
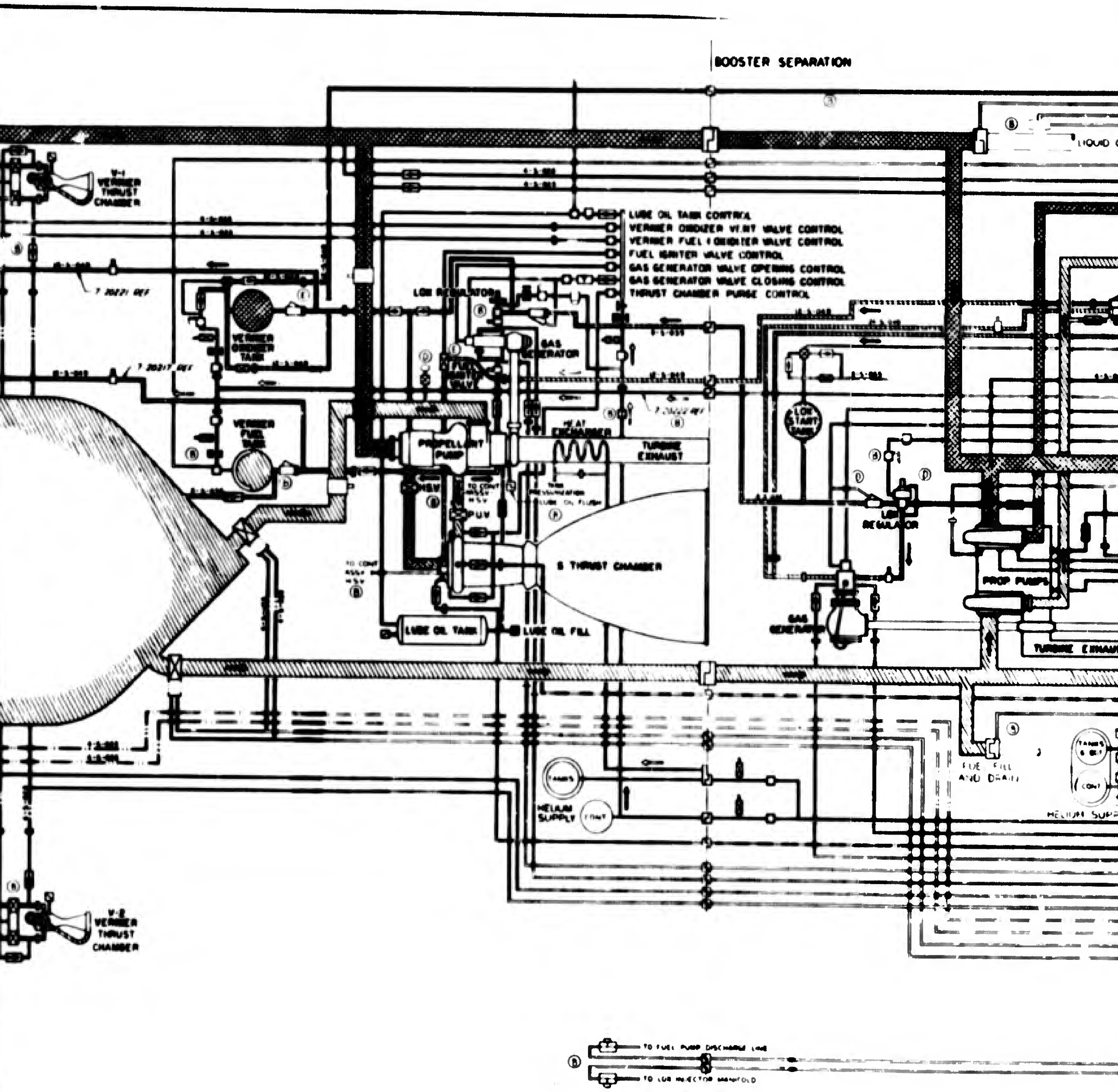


Figure 2. Liquid Oxygen Supply System, XSM-65 Series B

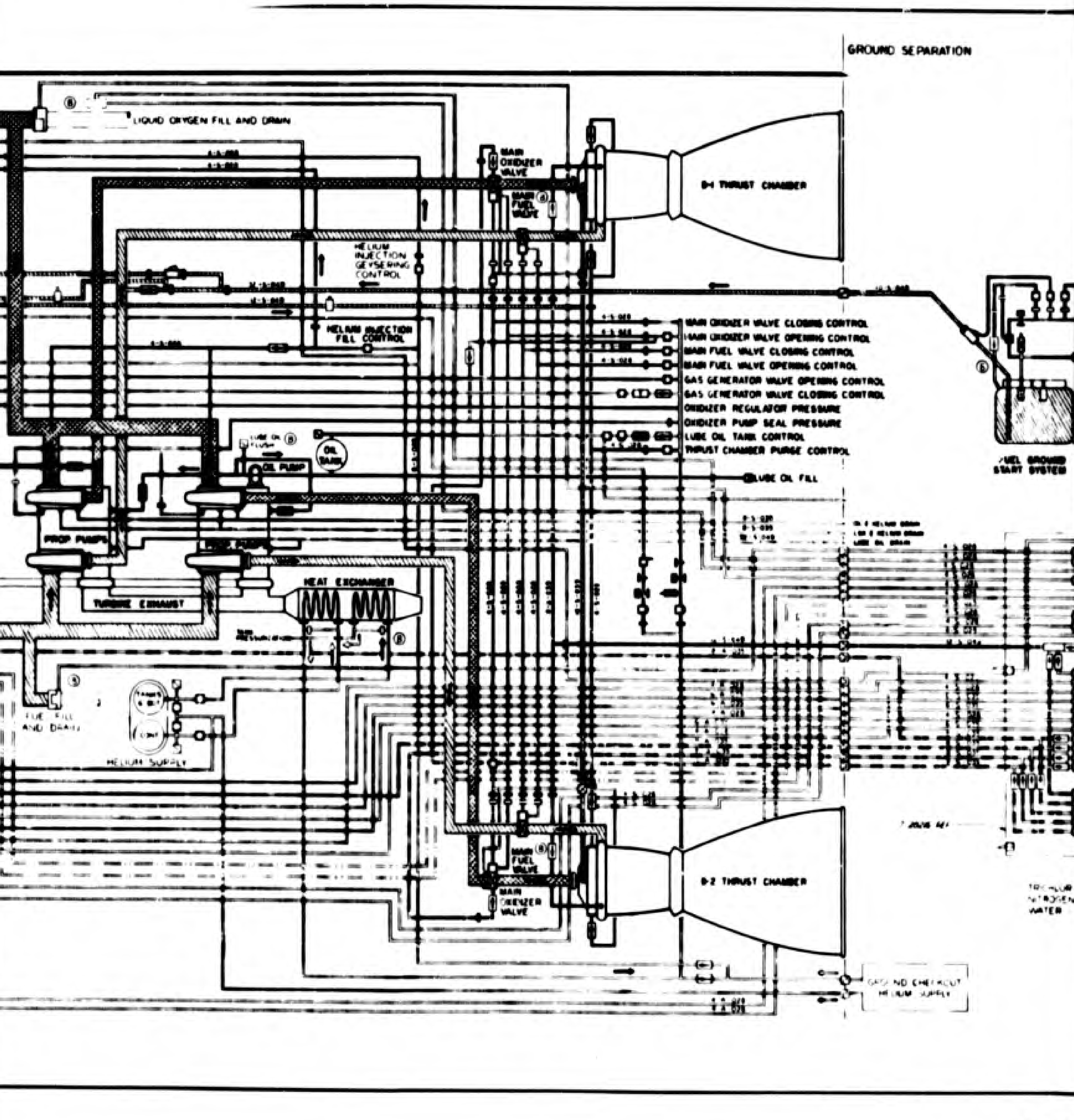


51-215 (C)

A.


BOOSTER SEPARATION
LIQUID
V-1 VERNIER THRUST CHAMBER
LUBE OIL TANK CONTROL
VERNIER OXIDIZER VENT VALVE CONTROL
VERNIER FUEL & OXIDIZER VALVE CONTROL
FUEL IGNITER VALVE CONTROL
GAS GENERATOR VALVE OPENING CONTROL
GAS GENERATOR VALVE CLOSING CONTROL
THRUST CHAMBER PURGE CONTROL
LOX REGULATOR
VERNIER OXIDIZER TANK
GAS GENERATOR
VERNIER FUEL TANK
PROPELLANT PUMP
HEAT EXCHANGER
TURBINE EXHAUST
LOX START TANK
LOX REGULATOR
S THRUST CHAMBER
PUV
LUBE OIL TANK
LUBE OIL FILL
GAS GENERATOR
PROP PUMPS
FUEL FILL AND DRAIN
HELIUM SUPPLY
V-2 VERNIER THRUST CHAMBER
TO FUEL PUMP DISCHARGE LINE
TO LOX INJECTOR MANIFOLD

B.


GROUND SEPARATION
LIQUID OXYGEN FILL AND DRAIN
MAIN OXIDIZER VALVE
MAIN FUEL VALVE
B-1 THRUST CHAMBER
HELIUM INJECTION GEYSERING CONTROL
HELIUM INJECTION FILL CONTROL
MAIN OXIDIZER VALVE CLOSING CONTROL
MAIN OXIDIZER VALVE OPENING CONTROL
MAIN FUEL VALVE CLOSING CONTROL
MAIN FUEL VALVE OPENING CONTROL
GAS GENERATOR VALVE OPENING CONTROL
GAS GENERATOR VALVE CLOSING CONTROL
OXIDIZER REGULATOR PRESSURE
OXIDIZER PUMP SEAL PRESSURE
LUBE OIL TANK CONTROL
THRUST CHAMBER PURGE CONTROL
LUBE OIL FILL
OIL PUMP
OIL TANK
PROP PUMPS
TURBINE EXHAUST
HEAT EXCHANGER
FUEL GROUND START SYSTEM
FUEL FILL AND DRAIN
HELIUM SUPPLY
MAIN FUEL VALVE
MAIN OXIDIZER VALVE
B-2 THRUST CHAMBER
GROUND CHECKOUT HELIUM SUPPLY

Figure

c.

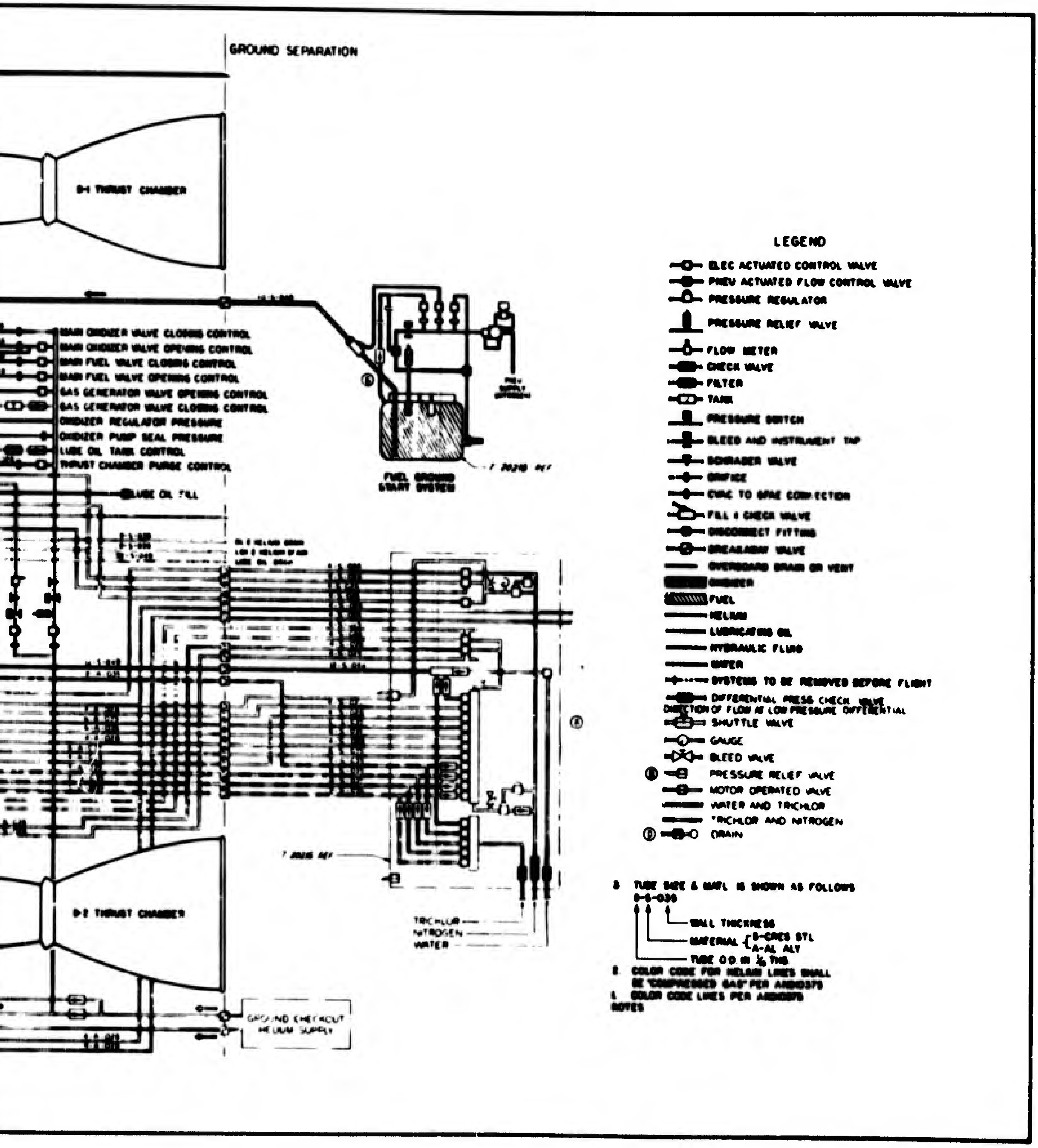
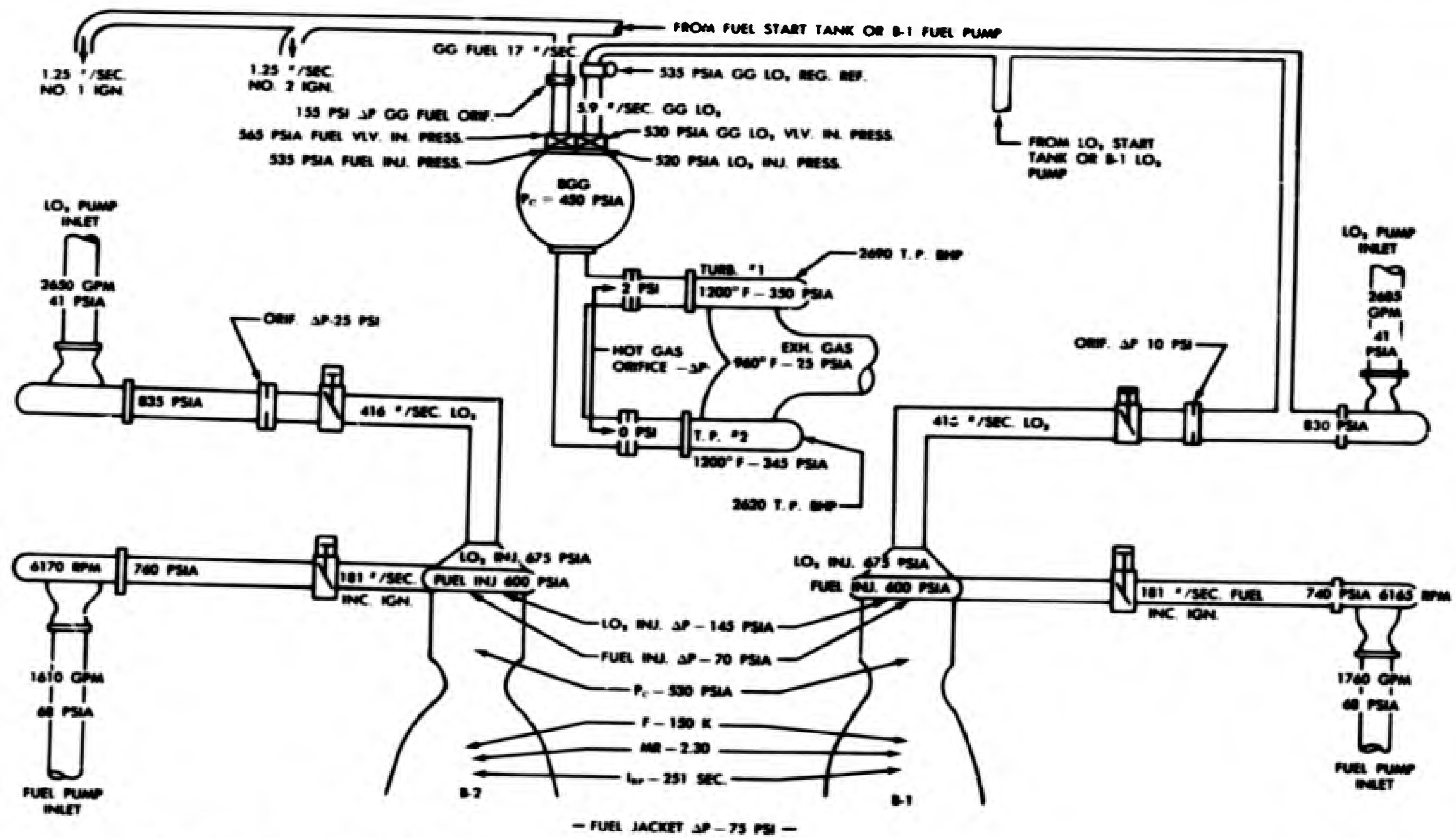


Figure 3. Propulsion System Schematic



RATED ENGINE PERFORMANCE VALUES

THRUST – 300,900 LBS.
I_{sp} – 247 SEC.
MR – 2.21
SP. GR. LO$_2$ – 1.13
SP. GR. RP-1 – .808

31 216 C

Figure 4. MA-1 Booster Steady State Nominal Performance Schematic

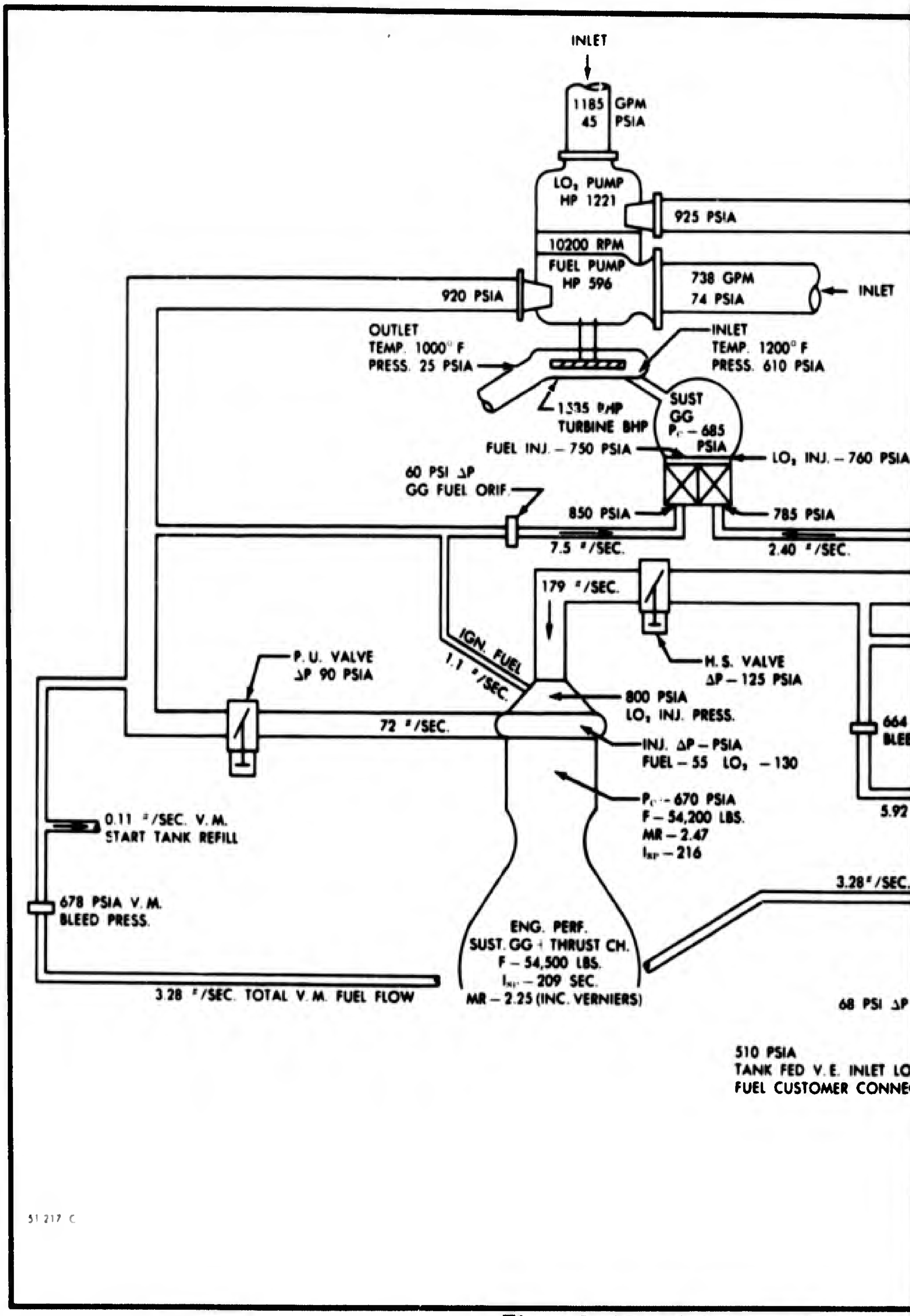


Figure 5. MA-1 Sustainer and Vernier

A.

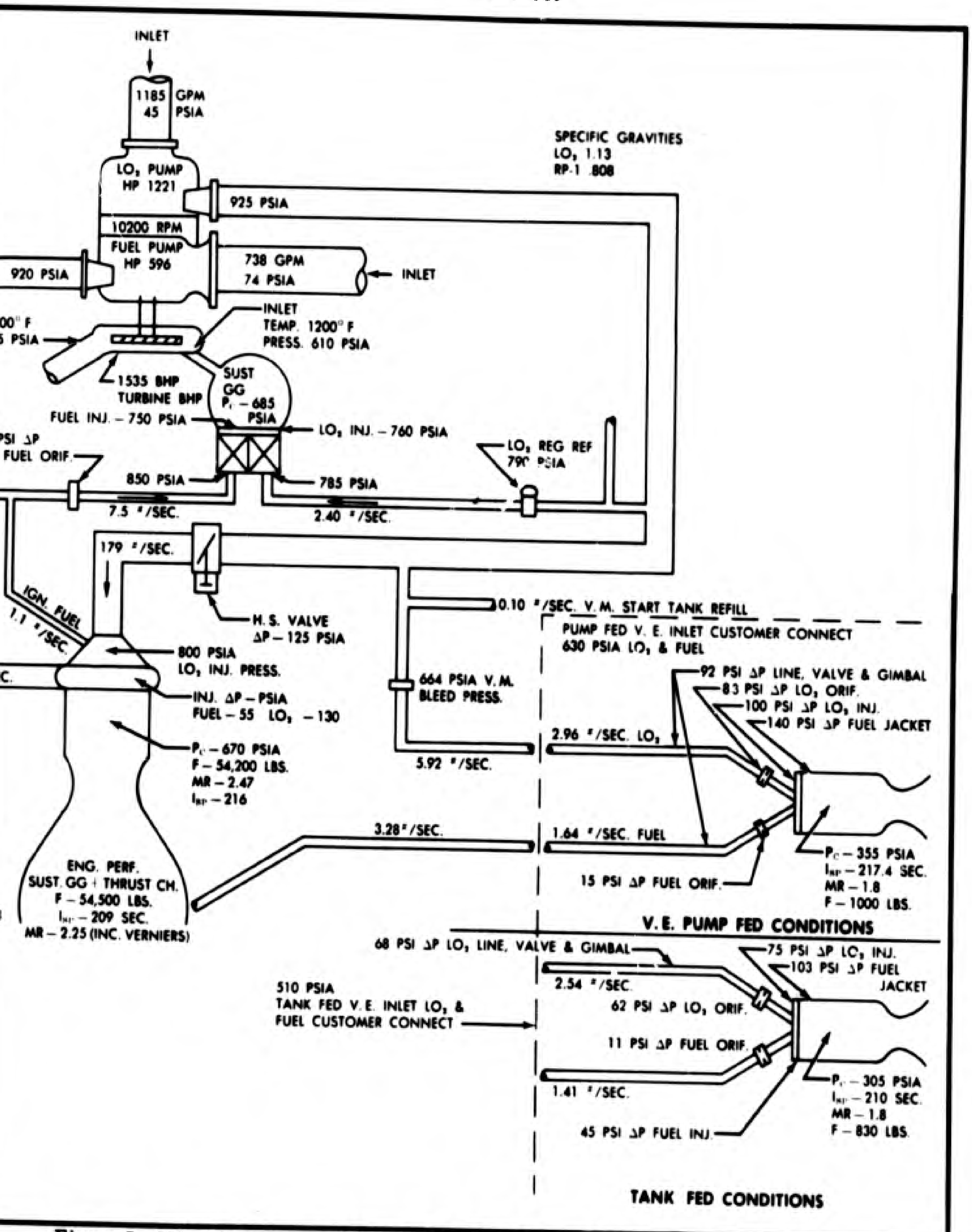


Figure 5. MA-1 Sustainer and Vernier Engines Steady State Nominal Performance Schematic

B.

2.0 XSM-65 SERIES B AND C PROPULSION SYSTEM

2.1 BOOSTER ENGINE

2.1.1 General Description. The MA-1 booster rocket engine has two thrust chambers, each rated at a thrust of 150,000 pounds at sea level ± 3%. This engine is identified as the XLR89-NA-1 rocket engine and conforms to Rocketdyne Specification Number R441S. The booster engine operates on liquid oxygen and RP-1 fuel. These propellants are provided to the thrust chambers from the missile tanks by means of turbine driven propellant pumps. There is one turbopump assembly for each thrust chamber, which for handling and mounting purposes are combined into a single power package assembly.

The forward, or Number 1, turbopump assembly provides fuel and oxidizer to the Number 1 booster thrust chamber. The aft, or Number 2, turbopump assembly provides fuel and oxidizer to the Number 2 booster thrust chamber.

The turbines which drive the booster propellant pumps are powered by a single gas generator. The gas generator is started on propellants which are supplied by pressurized start tanks. When a turbine speed is attained which is high enough to sustain operation, the start tanks are vented, and fuel and oxidizer continue to be supplied to the gas generator by the Number 1 turbopump assembly. The fuel start tank is a ground installation mounted on the launcher with suitable connections to the missile, and the liquid oxygen start tank is a part of the engine within the missile thrust structure.

Within the booster engine turbopump exhaust duct are two heat exchangers. For satisfactory weight economy in the missile, it is necessary to store the helium gas used for tank pressurization and engine controls at a very low temperature. The heat exchangers are used to heat the low temperature gas prior to its use in order to benefit from the volumetric increase which comes from heating. One heat exchanger is used to heat the gas required for missile tank pressurization, while the other, of smaller capacity, is used to heat the gas required for engine control.

2.1.2 Installation Features and Terminology, Booster Engine. Figures 1 and 2 show the arrangement of the booster engine assembly, sustainer engine assembly and vernier engine assembly on the missile structure. The missile is divided into four quadrants. Throughout this handbook, the major components of the rocket engine will be identified by the following terminology.

a. No. 1 Turbopump - This is the forward turbopump as installed in the missile thrust structure. It supplies propellants to the No. 1 thrust chamber assembly and to the booster gas generator.

b. No. 2 Turbopump - This is the aft turbopump as installed in the missile thrust structure. It provides propellants to the No. 2 thrust chamber assembly.

c. No. 1 Thrust Chamber - This chamber is located on the Y-Y axis between quadrants 1 and 4.

d. No. 2 Thrust Chamber - This chamber is located on the Y-Y axis between quadrants 2 and 3.

e. No. 1 Vernier Engine - This engine is located on the X-X axis between quadrants 3 and 4.

f. No. 2 Vernier Engine - This engine is located on the X-X axis between quadrants 1 and 2.

g. Pump and Drive Assembly - The pump and drive assembly is located within the thrust structure in quadrant IV, with attachment points on the thrust structure frame. Its positioning is such that a 12° angle exists between the X-X axis and the normal to the turbopump axis of rotation. The thrust structure to which the booster engine is attached is designed to react the forces created by rocket engine operation both through its own rigidity, and by distribution of the loads through the structure to the main tanks.

The booster thrust chambers are attached to the thrust structure on the Y-Y axis by means of gimbal joints. These gimbal joints permit swiveling of the thrust chambers, a function which is required to allow orienting of the missile in the prescribed flight path. Gimbaling is accomplished by means of hydraulic actuators, which are attached at one end to the missile thrust structure and at the other to outriggers provided on the thrust chambers. There are two hydraulic actuators per thrust chamber, located 90° apart, so that gimbaling can be achieved in desired directions. The propellant lines between the thrust chambers and the turbopumps are provided with flexible joints, to accommodate the deflections imposed by gimbaling action.

The effect of gimbaling is to displace the line of thrust. Directional control of the missile can, therefore, be achieved by suitable programming of thrust chamber deflections.

2.1.3 Performance - Booster Engine. The diagram and data shown in Figure 4 reflect the design parameters and the performance data expected of the XSM-65B booster engine. These data are nominal values and are to be used as guides only, since in certain cases considerable variation may be tolerated if over-all engine performance is not affected. These data are for sea level operation and are based on a propellant combination of liquid oxygen and RP-1 fuel. Liquid Oxygen - Specific gravity 70.6 lb/cu ft @ 10 psig @ -289°F. RP-1 - Specific gravity 50.40 lb/cu ft @ 70°F.

2.2 VERNIER ENGINE

2.2.1 General Description. The XSM-65 Series B missile requires two vernier engines, each of which is rated at 1000 pounds of thrust ± 3% at sea level under pump fed conditions. The vernier engines are mounted on the X-X axis of the missile (Figure 1) at a point just forward of the tangent point on the fuel cone.

The vernier engines are started with propellants supplied from two start tanks which are mounted upon the jettison tracks in quadrants IV and II. The start tanks are vented soon after booster engine operation has been attained, and operation is continued on propellants supplied by the sustainer turbopump assembly.

The vernier engine start tanks are provided in a package which includes the valves and regulators required for filling, pressurizing, and venting the start tanks.

Filling of the vernier engine liquid oxygen start tank takes place by gravity flow when the main missile tank is loaded. Filling of the vernier engine fuel tank requires pressurizing the bladder to expel all air from the liquid side of the vernier tank during main fuel tank tanking. The bladder is then vented allowing fuel from the main tank to fill the vernier tank by gravity flow. The liquid side of the vernier fuel tank is vented into the main fuel tank while the pressurizing gas within the vernier fuel bladder is vented overboard. The vernier oxidizer tank is also vented overboard.

The vernier engine oxidizer lines are bled by means of bleed valves located at the vernier engine customer connect panel. These valves are closed automatically when the engine start tanks are pressurized. Provisions for bleeding the vernier fuel lines are not required.

The vernier engine start tanks are vented at the same time that the booster engine start tanks are vented. These vernier start tanks are refilled through small orifices provided in the start tank check valve seats during the period of sustainer engine operation. The intent of the refilling operation is to allow operation of the vernier engines from pressurized start tanks after the sustainer engine has been shut down.

The vernier engines on the XSM-65 Series B will be gimbaled in the pitch and yaw axis. Gimbaling capability is represented by a full travel of ± 76° in pitch-roll and ± 36° in yaw. Vernier engines are gimbaled only after booster engine cutoff.

Each vernier thrust chamber is provided with a pressure switch for sensing chamber pressure. These pressure switches provide the electrical signal for booster engine ignition, and thus serve as an indication that satisfactory vernier engine operation has been achieved prior to attempting main stage operation.

2.2.2 Installation Features and Terminology, Vernier Engines. Referring to Figure 1, it can be seen that the vernier engines are mounted on the X-X axis. The Number ~~1~~ 2 vernier engine is mounted between quadrants I and II, and the Number ~~2~~ 1 engine between quadrants III and IV. The bases of the vernier engine mounting frames are located on missile station line 1132.7. The axis of the vernier engine thrust chambers is positioned at an angle of 30° during booster stage and 50° during sustainer stage to the missile longitudinal (Z-Z) axis, when in the null position, so that the exhaust is directed away from the missile body.

Propellants to the vernier engines are supplied by the sustainer turbopump after starting has been accomplished from the vernier fuel and oxidizer tanks. The propellant lines to the individual vernier engines manifold together before connecting to the fuel and oxidizer start tanks and sustainer pump outlet ports. The common fuel and oxidizer lines are orificed at the pump outlet bleed port to reduce the high pump pressures to a level required by the venier engines for rated operation.

Control valves for actuating the vernier engine propellant valves and the oxidizer bleed valves are mounted on the sustainer engine pneumatic manifold. Shown in Figures 15 and 25 are schematic diagrams depicting the vernier oxidizer and fuel systems, respectively.

2.2.3 Performance, Vernier Engines. Performance data of the vernier engines is indicated for both pump fed and tank fed conditions on the diagram, Figure 5.

2.3 SUSTAINER ENGINE

2.3.1 General Description. The sustainer engine is mounted at the apex of the fuel cone. The tank cone provides the necessary rigid structure for mounting the gimbals and hydraulic actuators of the sustainer engine thrust chamber.

This engine provides the missile with 54,500 pounds of thrust at sea level.

The sustainer engine is identified as the XLR105-NA-1 rocket engine and is governed by Rocketdyne Specification Number R441S. This engine uses liquid oxygen and RP-1 fuel from the same tanks as the booster engine. The propellants are provided to the sustainer thrust chamber by means of turbine driven propellant pumps with flow control being provided by means of the engine head suppression valve and propellant utilization valve, a description of which follows in section 2.3.5. The sustainer turbopumps provide propellants to the vernier engines during the entire period that the sustainer engine is operating. The sustainer turbopump assembly is mounted on the sustainer thrust chamber.

The sustainer turbopump also drives a hydraulic pump. This hydraulic pump is the source of power required for flight and engine control purposes for the sustainer engine during the booster and sustainer phases of powered flight.

Within the sustainer engine turbopump exhaust duct is a heat exchanger. This heat exchanger is used to heat the low temperature helium gas for pressurizing the missile liquid oxygen tank, and this only during the period after staging. No need exists for continuing to pressurize the missile fuel tank after staging.

2.3.2 Installation Features and Terminology. Figures 1 and 2 show the arrangement of the sustainer engine installation. The tank cone provides the necessary rigid structure for mounting the gimbals and hydraulic actuators of the sustainer engine thrust chamber. The gimbal joint mounted on the apex of the fuel cone permits swiveling of the thrust chamber, a function which is required to allow orienting of the missile in the prescribed flight path during the sustainer stage of flight. There are two hydraulic actuators on the thrust chamber, located 90° apart, so that gimbaling can be achieved in desired directions. The propellant lines between the main tanks and the turbopumps are provided with flexible joints to accommodate the deflections imposed by gimbaling action.

Unlike the booster engine where the thrust chamber turbopumps and gas generator are separately mounted, the sustainer thrust chamber serves as the mount for the sustainer turbopump, the gas generator, pneumatic manifold, and related valves and regulators, making it a compact rocket engine assembly.

2.3.3 Performance, Sustainer Engine. The performance of the sustainer engine is indicated on the schematic diagram, Figure 5.

2.3.4 Starting Sequence. The starting sequence and the start tank venting sequencing on the sustainer occur simultaneously with the booster engine sequencing, since both systems are supplied by the same start propellant sources. The engine starting and cutoff sequencing are shown in Figures 28 and 29.

2.3.5 Sustainer Engine, Head Suppression and Propellant Utilization Control System.

Method of Operation. Figure 6 illustrates schematically the configuration of the head suppression and propellant utilization systems as delivered on the Rocketdyne engine. The sequencing of the engine valves is controlled by four solenoid 3-way valves, A, B, E, and F, and proceeds in the following order. At ignition start the main liquid oxygen valve is electrically signalled to open by energizing relays K54C2 and K52C1 in the ground electrical box. These relays energize solenoid valves A and B, respectively, and hydraulic oil is vented from the large area side of the main liquid oxygen valve actuator to hydraulic return. Hydraulic pressure is continuously applied to the small area side of the actuator and the valve opens.

When the ignition detector links break, the gas generator igniters are signalled to fire. When the gas generator igniter link breaks, an electrical signal is given to relay 2K72C, sustainer flight lock-in, in the engine relay box. This relay locks solenoid valve A into the missile bus in the engine relay box. It also energizes relays 2K72F in the engine relay box and 2K73C in the ground electrical box. Relay 2K72F energizes solenoid valve E from the missile power bus in the engine relay box and 2K73C energizes solenoid valve F from the ground power. Energizing valves E and F opens the main fuel valve in a manner identical to the main liquid oxygen valve, and the engine goes into main stage.

Approximately 1.6 seconds after gas generator igniter links break, relay K82C, take-off simulator, energizes relay K84C which deenergizes solenoid valves B and F. This action permits the head suppression and propellant utilization valves to control. De-energizing solenoid valve B connects the hydraulic output of the head suppression servo

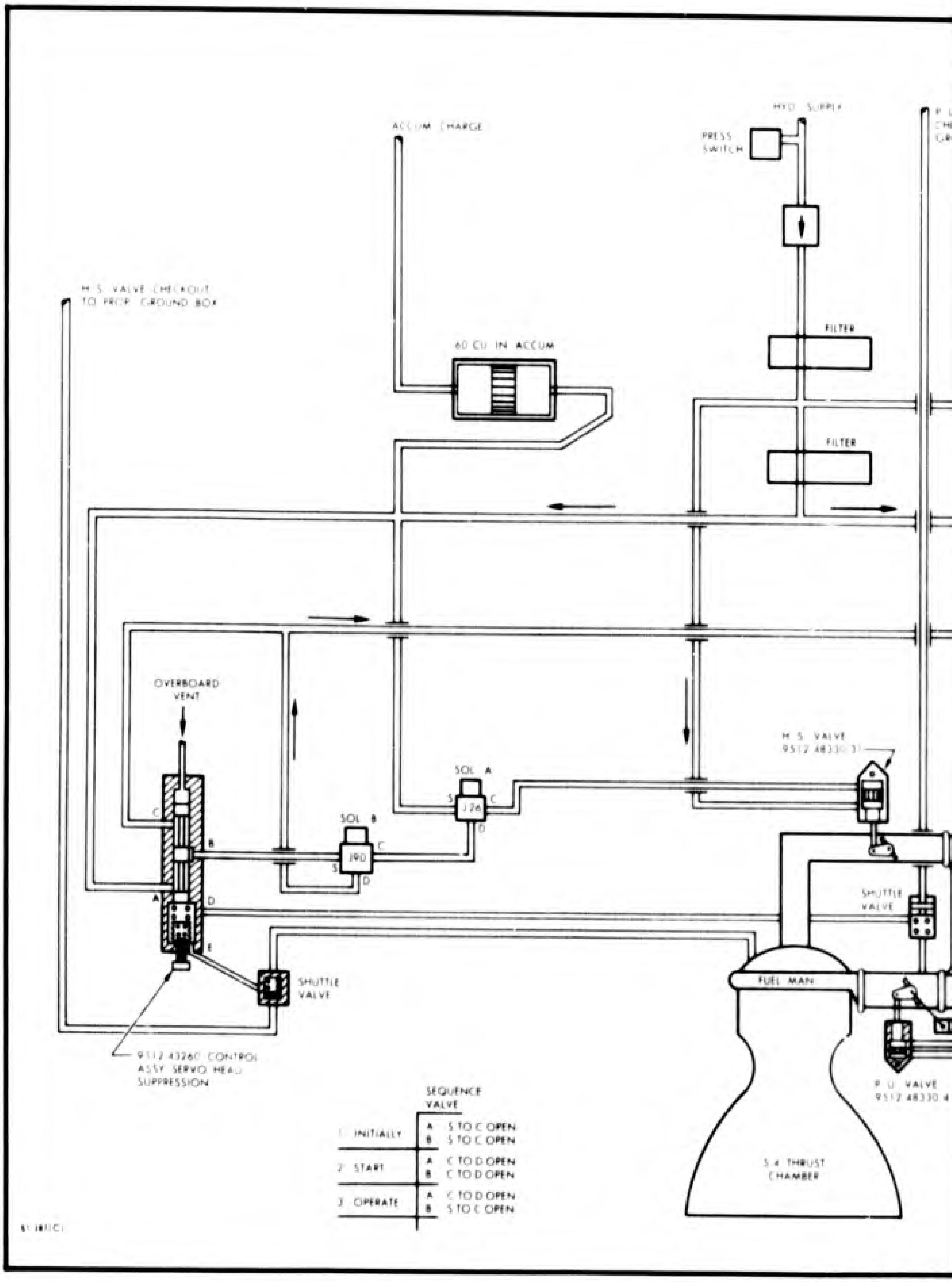


Figure 6. Sus

A.

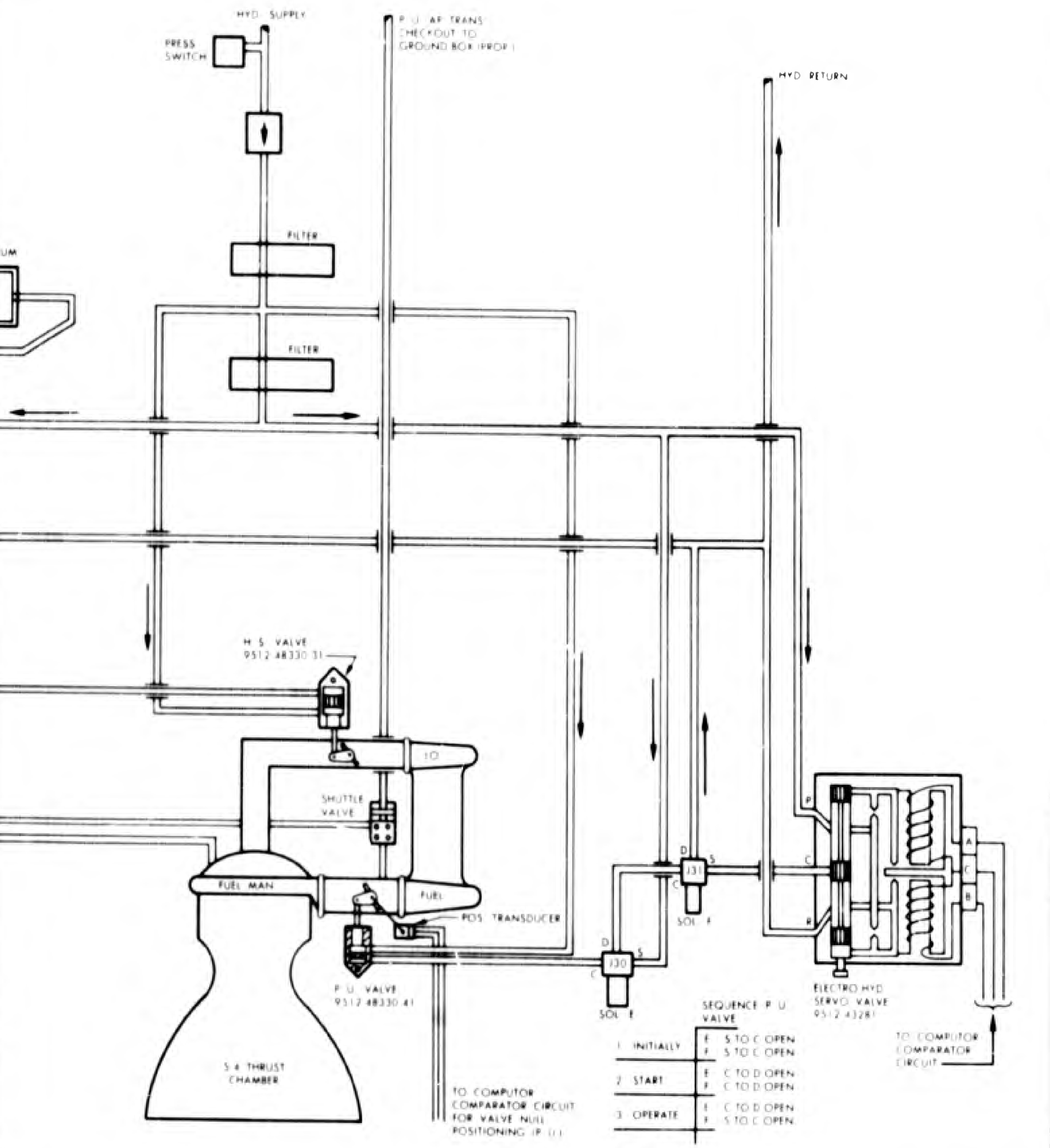


Figure 6. Sustainer Propellant Valves Control System Schematic

[redacted]

B.

to the control side of the main liquid oxygen valve actuator. Deenergizing solenoid valve F connects port C of the hydraulic servo valve to the control side of the PU valve actuator.

Turning on the head suppression control will position the main liquid oxygen valve by means of the servo controller so that the following relationship is maintained between fuel pump discharge pressure and liquid oxygen injection pressure.

$$P_L = 0.855\ P_f \pm K$$

P_L = Liquid oxygen injection pressure psig

P_f = Fuel discharge pressure psig

K = Constant which may be changed by adjustment on the servo controller

The controlling action is as follows. When the liquid oxygen injection manifold pressure is too high, the head suppression servo controller bellows is extended, so that hydraulic oil is metered from port A of the control to port B and, hence, to the closing side of the main liquid oxygen valve. The liquid oxygen valve starts to close and reduces the manifold pressure. Conversely, if the liquid oxygen injection manifold pressure is too low, the servo controller bellows will contract, causing hydraulic oil to be metered from the closing side of the main liquid oxygen valve actuator, and allowing the valve to open.

The main fuel valve positioning control operates by summing the demodulated output from a variable reluctance position indicator with a reference voltage in the computer comparator of opposite polarity, and of a magnitude corresponding to the control, or null position of the valve. The summed voltage is amplified and fed into the hydraulic servo control valve which positions the fuel valve by metering hydraulic flow to or from the large area of the actuator. The positioning of the PU valve gate for operation at nominal conditions is set by the magnitude of the reference voltage in the computer comparator.

At cutoff relay 2K72C deenergizes solenoid A and relay 2K72F deenergizes solenoid E, closing the main fuel and main liquid oxygen valves respectively.

Upon loss of either electrical or hydraulic power the main valves will close. During ground operation the loss of 28 volts electrical power will send a cutoff signal to the engine and deenergize all four solenoid valves, thus closing the main valves. A pressure switch with a dropout setting of 1000 ± 100 psig in the supply line to the engine hydraulic system provides protection in the event of hydraulic power loss. When pressure decays to the switch setting, cutoff is signalled by dropping relay K11H in the ground electrical box. System pressure can be maintained for a short period by the hydraulic accumulator, but will decay due to leakage through the hydraulic servo valve.

The position transducer on the PU valve is used to limit the excursion of the fuel valve to that which will permit a ± 15% change in sustainer engine mixture ratio. The voltage output is fed to the computer comparator unit. Movement of the main fuel valve past the limit stops is prevented by the electrohydraulic servo valve when limiting position of the valve is reached.

Head Suppression Valve Checkout. Prior to head suppression valve checkout the hydraulic accumulator must be precharged to 1000 psi and hydraulic pressure at 3000 psi must be supplied to the engine. The unit should be observed for the following discrepancies during component checks.

a. Unaccountable null shift of the head suppression control of over 4 psi.

b. Head suppression control deadband of over 8 psi.

c. Main propellant valves opening or closing time variation of over 10 milliseconds.

d. Faulty position indication, including closed and open lights, of the main valves.

e. System hydraulic or pneumatic leaks.

For components test the main liquid oxygen valve should be opened and closed 10 times and checked for repeatability of actuating times. The by-pass switch can then be actuated to place the valve in a control position and the following checks should be made. (During these tests the liquid oxygen valve is positioned by the head suppression servo control.)

Provision is made to apply null setting pressures to simulate the engine fuel pump discharge pressure and liquid oxygen pump injection pressures required at the nominal thrust and mixture ratio for a particular engine. These pressures are applied through a 1/2-inch fuel shuttle valve and a 1/4-inch liquid oxygen shuttle valve on the engine. Connections for these inputs are on the engine ground control box on the launcher.

With the main liquid oxygen valve open, supply the correct null setting pressures to the head suppression controller. These pressures are given in the engine log. The main liquid oxygen valve should close as the pressure rises and becomes stationary at some angle between full open and full closed when the null value is reached. Raise the liquid oxygen setting pressure to 4 psi above its null value. The main liquid oxygen valve should begin to close slowly. Lower the liquid oxygen setting pressure to 4 psi below its null value. The liquid oxygen valve should begin to open slowly. Deactuate the by-pass switch and close the main liquid oxygen valve.

Adjustment of the head suppression controller is a special procedure and will be accomplished by qualified field representatives when required.

Propellant Utilization Valve Checkout. The checkout of the PU valve is associated with complete propellant utilization system checkout and is covered by procedure ZI-7-089. A components check on the PU valve consists of opening and closing the valve 10 times and checking for repeatability of actuating times. With the valve open the by-pass switch is actuated to place the valve in the control position for proceeding with PU system checks.

During an engine sequence check, the cutoff capability of the hydraulic switch should be checked. When the fuel and liquid oxygen valves are open, the hydraulic pressure should be cut off. As the supply pressure decays to 1000 ± 100 psig, the hydraulic pressure switch should initiate cutoff and both main valves should close. After the hydraulic pressure is cut off, the accumulator precharge pressure should decay from 3000 to 1000 psi within 5 minutes. If this pressure remains high, the hydraulic servo valve should be removed and the hydraulic system checked for sources of contamination.

Data on Components Comprising the System.

1. In general, the components are precision made electrical and/or mechanical assemblies involving small dimensions and close tolerances. Improper use, adjustment, or assembly will make the system inoperative.

   a. Data presented on components is either from actual test or from specifications which the component must meet or exceed. In either case, a small variation from one part to another is to be expected.

2. Control Assembly Servo Head Suppression 9512-43260 (Figure 6).

   a. Proofing pressures.

Port	Pressure (psig)
A, B, C (simultaneously)	6000
D and E (simultaneously)	2150
D with E vented	195 (no leakage)

b. The 3-ply stainless steel bellows has been pressurized, without leaking, to 2150 psi Delta P. At 1800 psi Delta P the elastic limit has been exceeded and the bellows takes on a permanent "set."

c. The maximum flow through the control is 5.5 gpm at 1500 psi Delta P from A to B and F, or B and F to C. (Supply to control or control to drain.)

d. Leakage will not exceed 5 cc/min from A to C at 3000 psi Delta P. (Supply to drain.)

e. Hydraulic oil leakage into the fuel sensing cavity is approximately 5 cc/min with the fuel cavity at 0 psig.

3 Valve Assembly Hydraulic Servo 9512-43281.

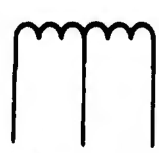
a. The only servo valve that will be furnished for engine use in the near future is the FC 2-90 supplied by the Cadillac Gage Co. The following information applies only to this particular servo valve.

b. Proofing pressures (for assembly).

Port P and C	6000 psi
Port R	1500 psi

c. Maximum flow is .47 gpm from P to C or from C to R at 1500 psi Delta P.

d. Electrical schematic:



DC resistance 1000 ± 75 Ω /coil.
With current from B to A > B to C the hydraulic flow is from C to R;
with current from B to A < B to C the hydraulic flow is from P to C.

4. Solenoid Valve 9512-958013.

This is a 2-position 3-way direct solenoid actuated normally open valve for 3000 psi hydraulic service. Solenoid valves A, B, E, and F are of this type (Figure 6).

a. Proof pressure. 4500 psi applied to ports 1, 2, and 3 simultaneously.

b. At a flow of 3.2 gpm of hydraulic oil at 70° to 100°F, the pressure drop should be less than 55 psi from ports 1 to 2 or 2 to 3. Leakage should be less than 5 cc/min in either direction at 3000 psi Delta P.

c. The opening or closing response time is defined as the time required from the instant the solenoid is signalled electrically to open or close the valve until the pressure directly downstream of the valve builds up to the operating pressure or decays to zero. The valve operating time is 0.040 second to open (deenergizing time) and 0.070 second to close (energizing time) at 3000 psig operating pressure and 18 V DC.

d. The resistance is approximately 27 ohms and the current drain 1 amp at 70°F. The pull-in voltage varies from approximately 14 to 17 volts with continuous duty at a flow of 3.2 gpm at 3000 psi. Drop-out voltage is approximately one volt with 3000 psi supply pressure.

5. Pressure Switch Hydraulic Supply 9512-948823 (Figure 6).

a. Proof pressure, 4500 psig into inlet port. No leakage allowable.

b. Setting 1000 ± 100 psig on drop-out. Differential pressure (between pick-up and drop-out) is 250 psi maximum.

c. Electrical data. Single pole double throw switch; pins A and B normally closed; pins B and C normally open. Operation at 18-30 volts DC.

6. Valve - 1/2-inch Shuttle 9571-959014. This valve is located in the head suppression control fuel sensing line.

a. Proofing pressure, 2250 psig applied simultaneously into all 3 ports.

b. Maximum operating pressure is 30 psig. This is the pressure required, applied at the normally closed port, to move the poppet over completely to the normally open port.

c. With 30 to 1500 psig applied into the NC port there will be no leakage out of the NO port. With no pressure on the NC port and pressures from 0-1500 psi in the system, there will be no leakage out of the NC port.

7. Valve 1/4-inch Shuttle 9571-959013. This valve is located in the head suppression control liquid oxygen sensing line.

a. Data is identical to that listed in paragraphs 6a, b, and c inclusive.

8. Valve Assembly Propellant Control 9512-48330 (HSV and PU) (Figure 6).

a. Data common to both main valves.
Actuator proofing pressure, 4500 psig.
Hydraulic actuator.

piston diameter	= 2.496 in.
piston diameter less shaft	= 1.747 in.
piston effective area	= 4.91 in.^{2}
piston effective area less shaft	= 2.40 in.^{2}
piston area ratio	= 2.05
total stroke	= 1.875 in.
maximum volume large side	= 9.20 in.^{3}
maximum volume small side	= 4.50 in.^{3}

b. Total travel of the gate is from 0° (fully closed) to approximately 87° (fully open). The open and closed position microswitches are set down 3° from full travel.

c. The fuel valve is equipped with a protractor and mechanical pointer to measure angular position and aid in instrumentation checks.

d. Main liquid oxygen valve data.

Electrical -

5 pin connector -

A - Thermostat
B - Microswitch heater
C - Common for microswitches
D - Open microswitch
E - Closed microswitch

110 volts at 60 cps across A and B. The microswitch heater on the valve draws 60 watts, on the -31 valve 100 watts.

28 volts DC to pin C

2 pin connector - actuator blanket heater

110 volts at 60 cps the heater draws 300 watts.

e. Main fuel valve data.

Electrical -

5 pin connector -

A - Blank
B - Blank
C - Common to both microswitches
D - Open microswitch
E - Closed microswitch
28 volts DC to pin C

f. The main fuel valve is equipped with a variable reluctance pick-up for angular position measurement. The pick-up is set to null at some midrange gate position for linearity purposes and requirements of Convair's propellant utilization system. Ultimately, this null must correspond to a gate angle at which nominal thrust and mixture ratio are achieved with the fuel at nominal density.

9. Accumulator MS 28700-3.

a. Proofing pressure, 4500 psig into both ports.

b. Leakage, no leakage is permissible in either direction across the actuating piston.

10. Check Valves.

a. Proofing pressure, 4500 psig.

b. The check valve in the pneumatic supply to the accumulator must have essentially zero leakage. The hydraulic valve should have a leakage of 5 cc/min or less. Leakage requirements are against reverse flow.

3.0 CONTROLS

3.1 GENERAL DESCRIPTION

The Propulsion System electrical controls can roughly be divided into two main groups.

1. Engine control circuitry as provided by Rocketdyne.

2. Tanking and purge controls.

All the propulsion electrical circuits are 28 V DC with the exception of the engine heaters which use 115 V AC 60-cycle ground power. The tanking and purge controls are all operated from ground power until flight lock-in, at which time the controls become solely dependent upon missile power.

The individual control circuits are described in detail in Rocketdyne's "Rocket Propulsion System" handbook No. R-113-2 and Convair Propulsion System Controls Report ZK-7-048.

4.0 GROUND FUEL START SYSTEM

4.1 GENERAL DESCRIPTION

The ground fuel start system is used to provide the fuel required for starting the booster and sustainer engines. The system uses a pressurized tank and supplies fuel for (1) ignition of the booster and sustainer thrust chambers, and (2) starting and operating the sustainer and booster gas generators until the respective turbopumps attain a speed which will permit bootstrapping or operating the gas generators with propellants provided by the sustainer and booster Number 1 turbopumps. Figure 7 shows the ground fuel start system schematically.

A description of the fuel start tank assembly is provided in Rocketdyne Handbook of Service Instructions R-162.

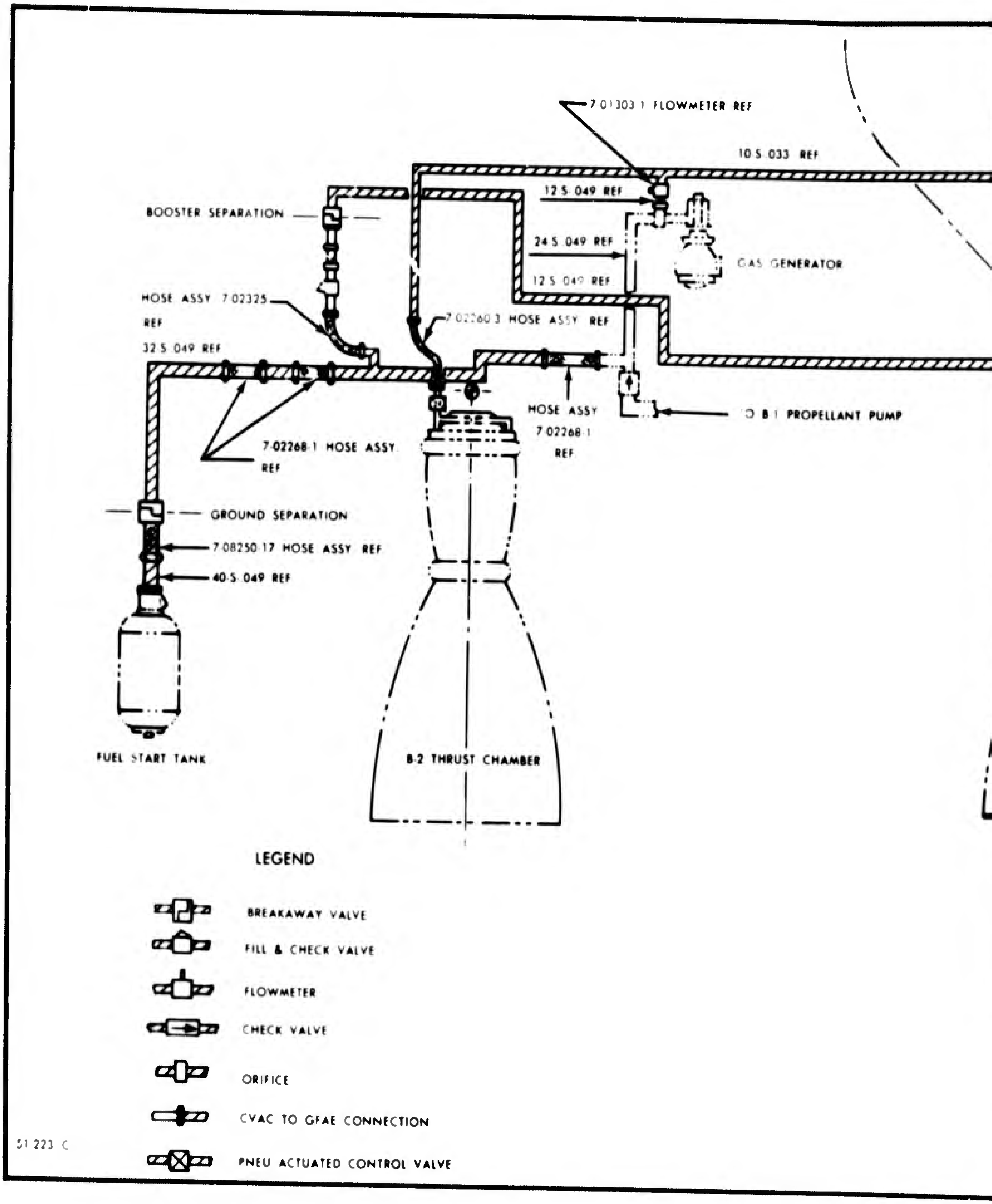
4.2 INSTALLATION FEATURES AND TERMINOLOGY

The fuel start tank is connected to the missile through a disconnect valve mounted on the missile disconnect pad in quadrant II. From the airborne half of the disconnect valve, the line is connected by means of a flexible line to a tee in the propellant line which leads from the No. 1 turbopump fuel discharge line to the gas generator propellant valve. Downstream of this tee is a 1-inch tee connection which diverts fuel flow to the sustainer gas generator and sustainer thrust chamber igniter. At the gas generator propellant valve, a tee is provided for installation of an igniter fuel line which is directed to an igniter fuel valve on each booster thrust chamber.

4.3 FUEL START BREAKAWAY VALVE, PART NO. 7-02241

Referring to Figure 8, it can be seen that the valve consists of an airborne half and a ground half. When in a connected position, i.e., with the missile in an erected position, the joining of the two sections causes the valve to open. Upon launching the missile, both halves of the disconnect valve are closed by springs which back the poppets.

The fuel start tank is located on the launcher in the quadrant II section of the missile. A 2-1/2-inch propellant line is connected to the fill and check valve from the missile disconnect valve. Filling of the fuel start tank takes place by gravity flow at an early stage of the missile fuel tanking operation. The fill and check valve is pneumatically opened to


7-01303-1 FLOWMETER REF
10-S-033 REF
12-S-049 REF
BOOSTER SEPARATION
24-S-049 REF
GAS GENERATOR
12-S-049 REF
HOSE ASSY 7-02325
REF
7-02260-3 HOSE ASSY REF
32-S-049 REF
HOSE ASSY
7-02268-1
REF
TO B-1 PROPELLANT PUMP
7-02268-1 HOSE ASSY
REF
GROUND SEPARATION
7-08250-17 HOSE ASSY REF
40-S-049 REF
FUEL START TANK
B-2 THRUST CHAMBER
LEGEND
BREAKAWAY VALVE
FILL & CHECK VALVE
FLOWMETER
CHECK VALVE
ORIFICE
CVAC TO GFAE CONNECTION
PNEU ACTUATED CONTROL VALVE
51-223-C

A.

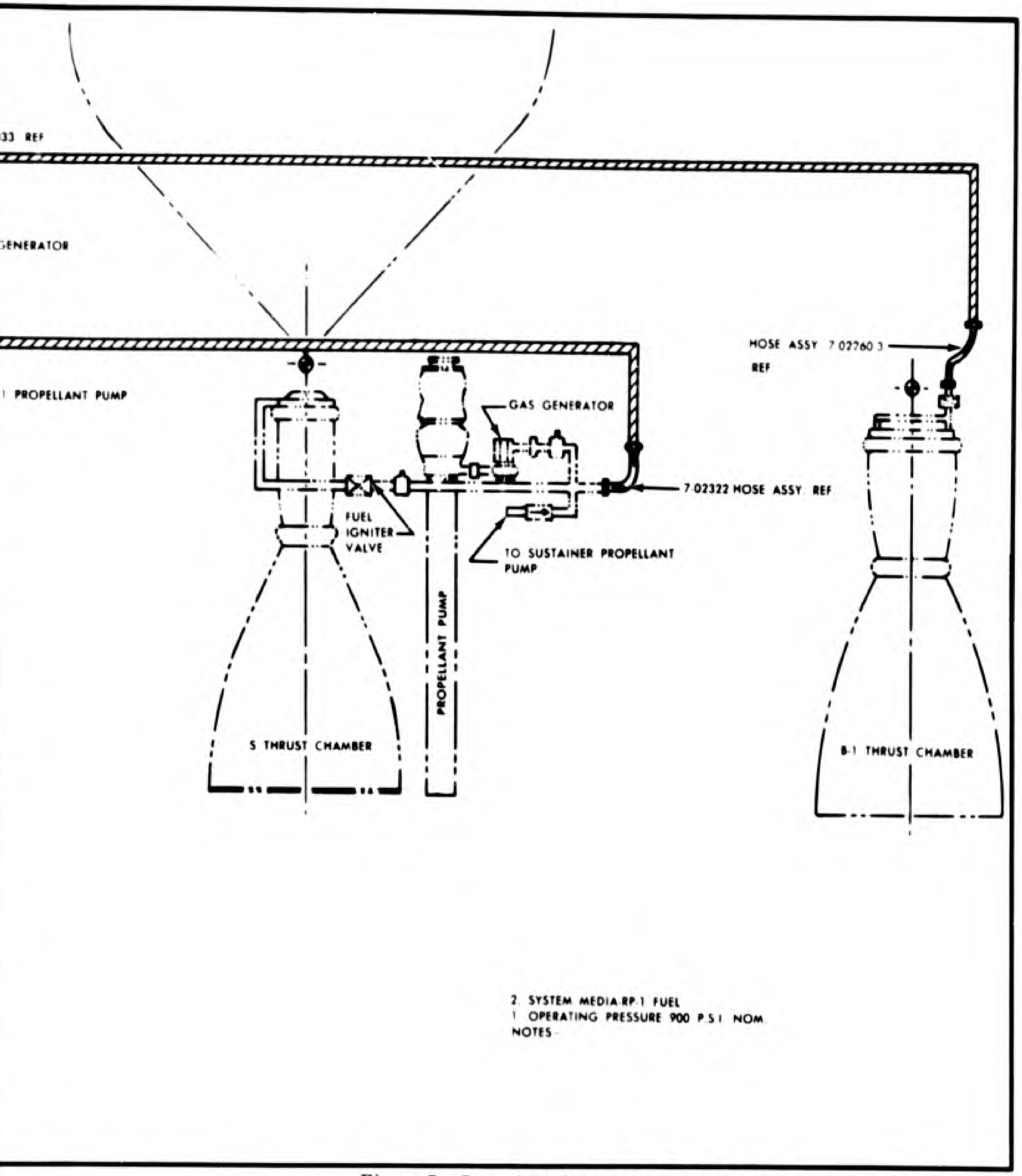
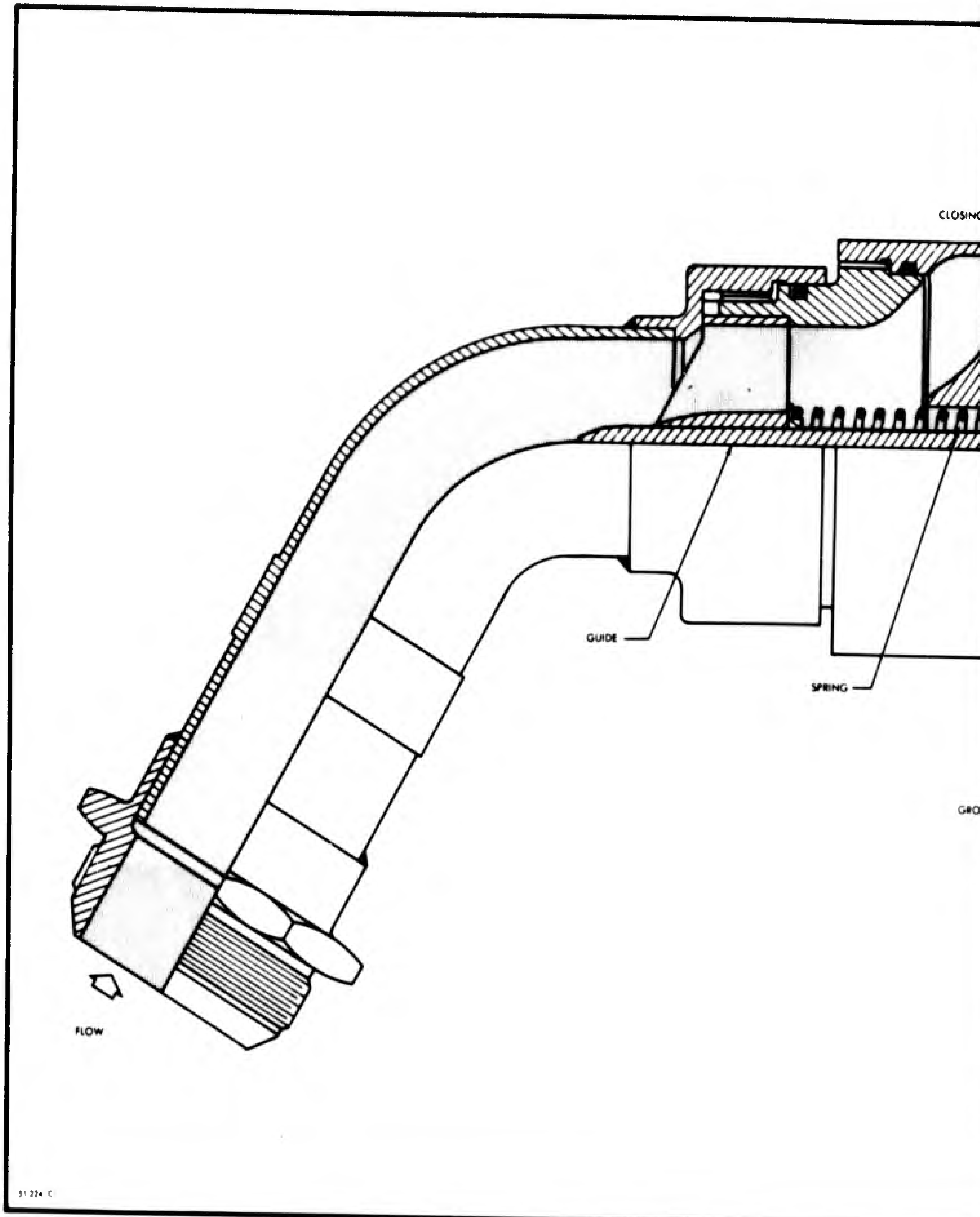


Figure 7. Ground Fuel Start System Schematic

B.



A.

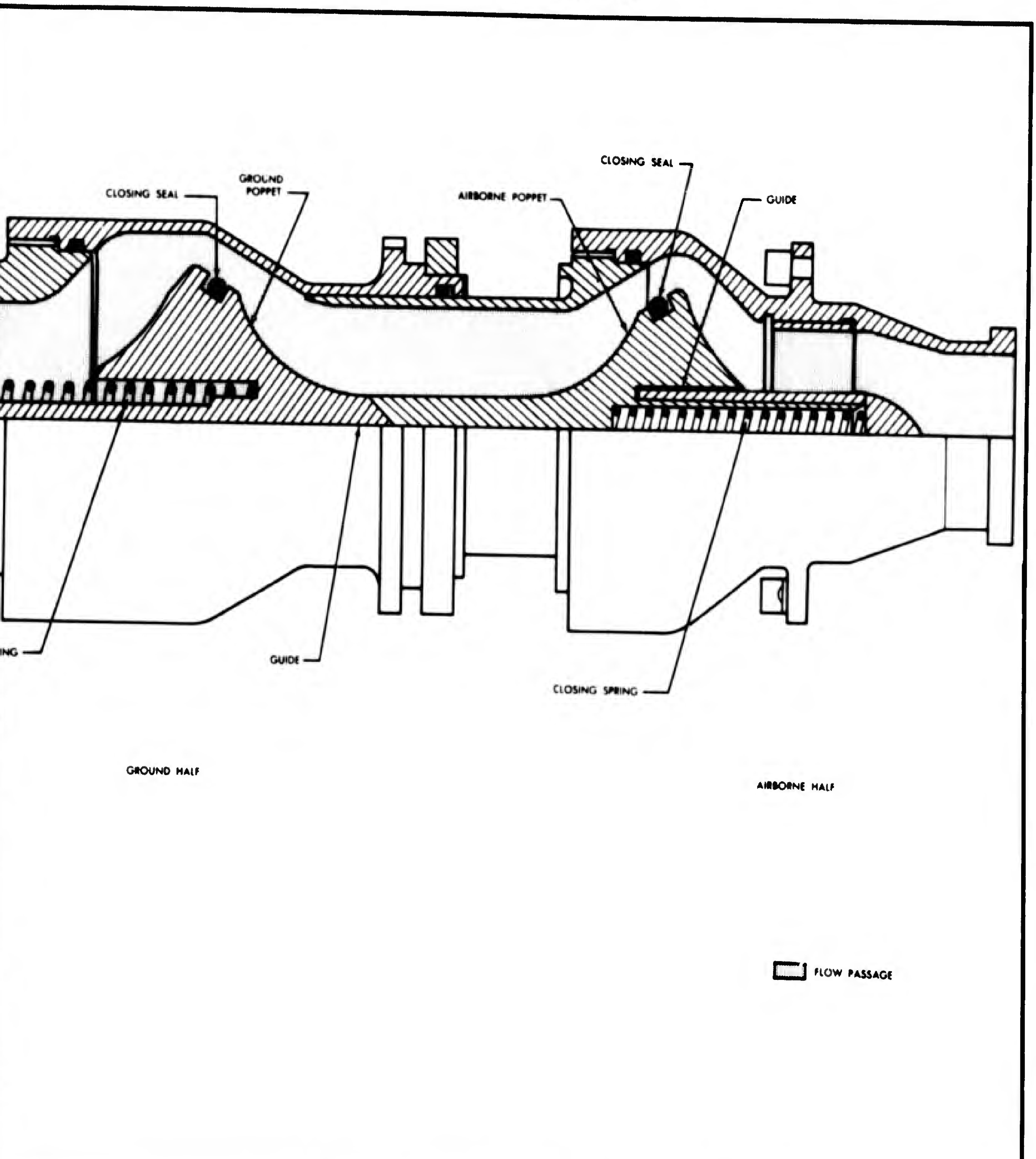


Figure 8. Fuel Start Breakaway Valve

B.

permit filling of the start tank When the start tank is full, a level switch is actuated which causes the vent valve to close and causes release of pneumatic pressure to the fill and check valve.

4.4 PERFORMANCE

The ground fuel start tank requires a minimum inlet pressure of 2000 psig nitrogen for satisfactory operation. The pressure at which the ground fuel start tank regulator is set is dependent upon the pressure drop characteristics of the line between the start tank and the customer connect point at the gas generator fuel feed line. Testing has shown that for this installation a fuel start tank pressure of 800 ± 10 psig is satisfactory for engine starting. The fuel start tank pressurizing valve is opened at a slow rate to prevent high transient pressures in the propellant line during initial pressurization. This is accomplished by means of a pneumatic delay system provided on the start tank assembly. (See Rocketdyne Handbook, Number R-162.) The nominal time between the start tank pressurizing signal to the start of pressurization is from one to two seconds.

5.0 LIQUID OXYGEN SUPPLY SYSTEM

5.1 GENERAL DESCRIPTION

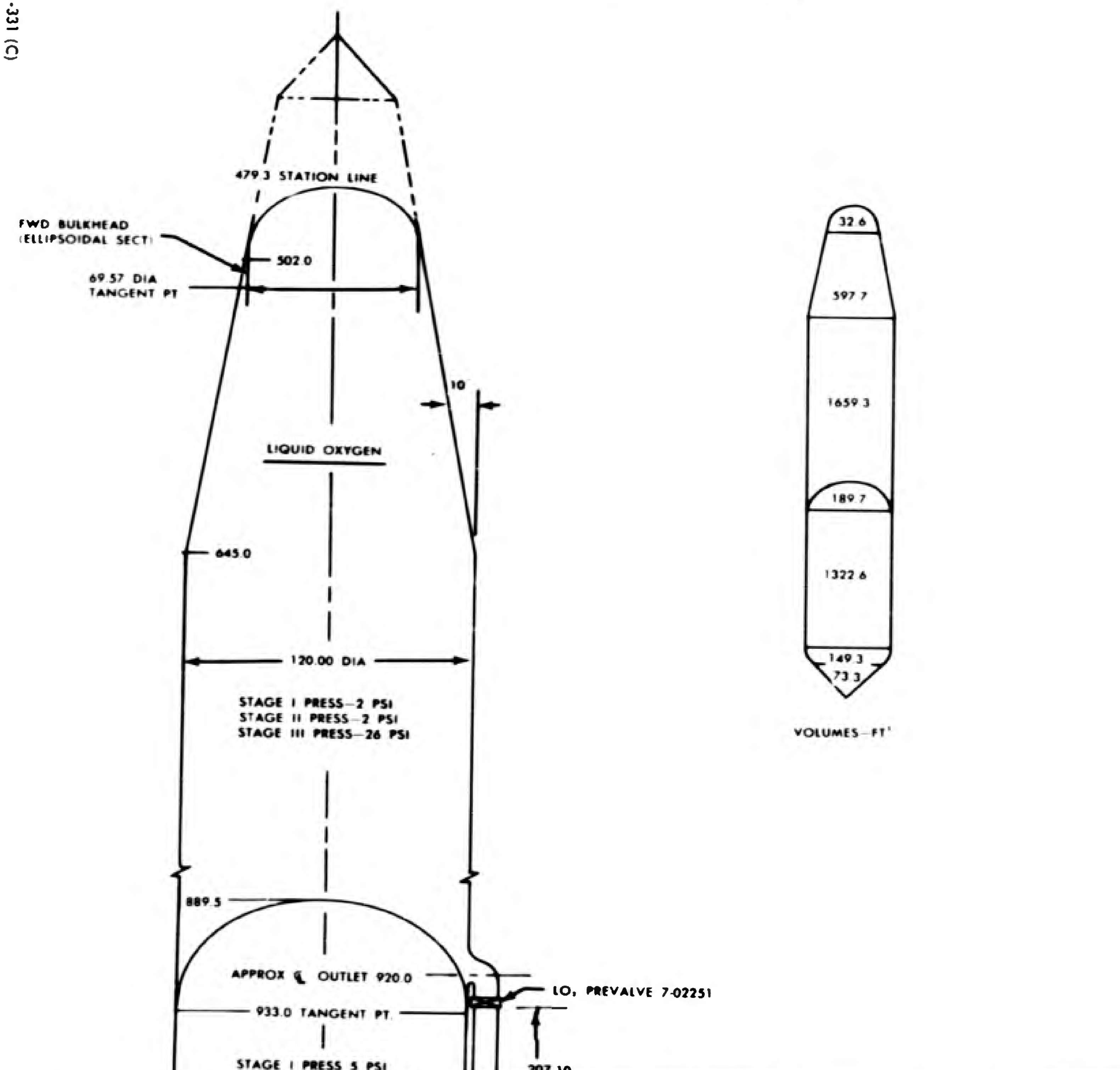
This system consists of the necessary ducting and valving to transport the liquid oxygen from the missile tank to the turbopump inlets. During the propellant tanking operation, the same ducting is utilized for filling the liquid oxygen tank through a missile fill valve and associated fill connections on the launcher. Drawing 7-20204 is the installation drawing for this system. The main liquid oxygen duct (as shown in Figure 9) is located in quadrant IV, 40° from the X-X axis. It is unique in that it is outboard of the missile skin proper. The following major subassemblies comprise this system. (See Dwg. 7-20204.)

5.1.1 Fill and Drain Valve. This valve is attached to the booster pump inlet liquid oxygen manifold at station 1223.45 and permits flow of liquid oxygen to the missile during the tanking operation. The valve consists of two halves; part number 7-02225-1 is the airborne assembly permanently attached to the missile, and part number 7-02226 is the ground fill nozzle or mating half permanently attached to the launcher oxidizer supply line (Figure 10). The mating halves of this valve are engaged when the missile is erected and are disengaged upon release of the missile. The engaging travel of the ground nozzle is a maximum of 1 inch and the maximum engaging force required is about 300 pounds. If the valve freezes upon engaging, the units will withstand a maximum disengaging force of 1500 pounds. The units may be engaged with a maximum of 1-1/2 degrees misalignment on the vertical axis. When engaged, the maximum force acting up on the airborne valve and down on the ground nozzle during the filling operation is about 2600 pounds. The force on the ground nozzle is reacted through a spring-loaded support jack to the launcher. The force on the airborne valve is reacted through the pump inlet manifold and manifold support installation to the missile thrust structure. Maximum permissible leakages for the valves are as follows:

Disengaged: Airborne Valve - 30 cc/min at 150 psig internal pressure.
Ground Nozzle - 50 cc/min at 10 psig internal pressure.
Engaged - Maximum external leakage not to exceed 10 cc/min with an internal pressure of 100 psig.
The maximum internal operating pressure during a fill or drain operation is 100 psig.

The airborne unit contains a poppet valve, held closed by spring force and liquid oxygen pressure. The actuating device for the airborne poppet is built into the ground half of the valve to reduce the weight of the flight equipment.

51-331 (C)



479.3 STATION LINE
FWD BULKHEAD (ELLIPSOIDAL SECT)
502.0
69.57 DIA TANGENT PT
10
LIQUID OXYGEN
645.0
120.00 DIA
STAGE I PRESS—2 PSI
STAGE II PRESS—2 PSI
STAGE III PRESS—26 PSI
889.5
APPROX ℄ OUTLET 920.0
933.0 TANGENT PT.
LO, PREVALVE 7-02251
STAGE I PRESS 5 PSI
32.6
597.7
1659.3
189.7
1322.6
149.3
73.3
VOLUMES—FT³

A.

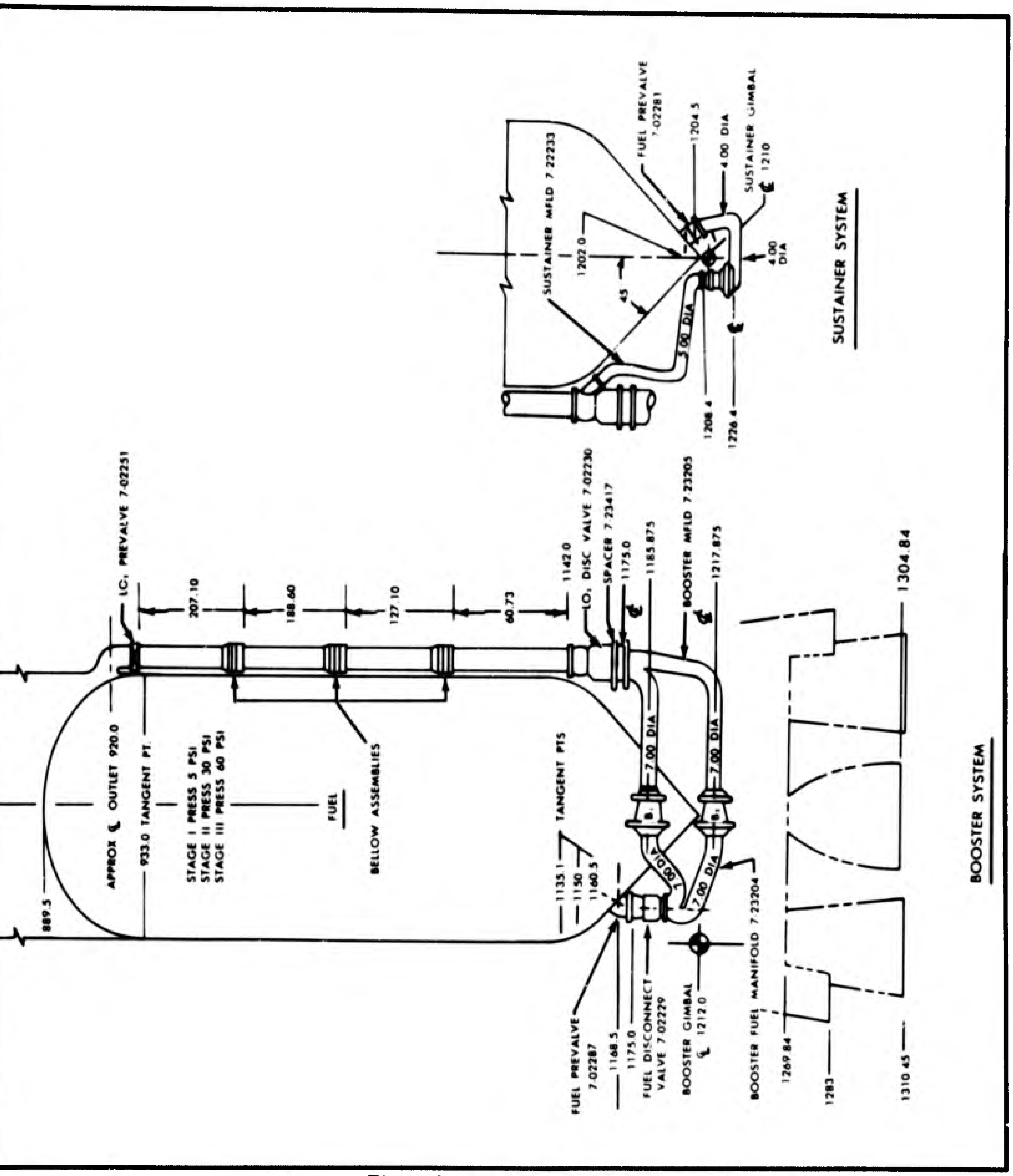


Figure 9. Propellant Supply Systems, Series B

B.

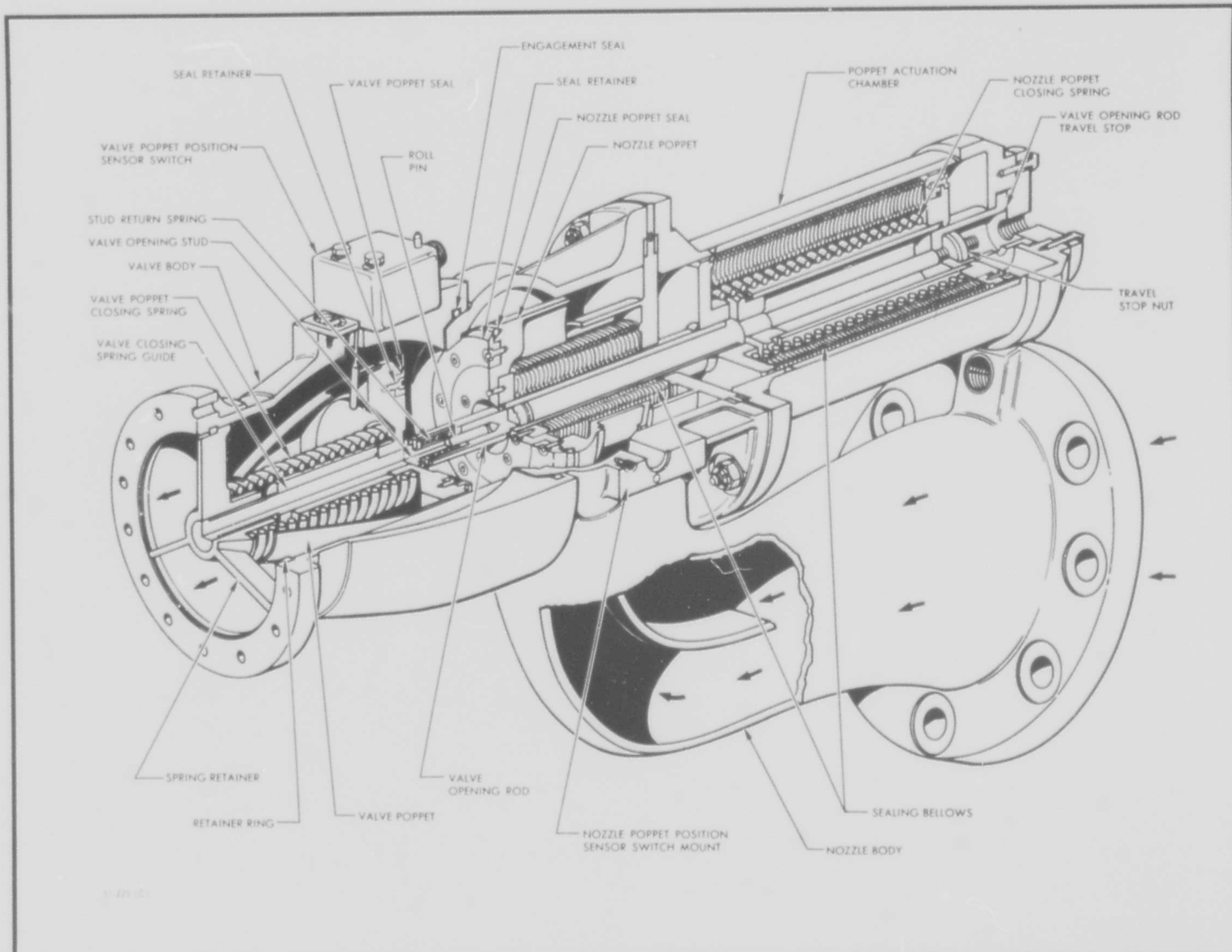


Figure 10. Liquid Oxygen Fill and Drain Valve and Nozzle

The ground half or nozzle is sealed with a spring-loaded poppet valve which is held closed until opened by the actuator. The ground half also contains a pneumatically operated bellows actuating device which opens the poppets in both the airborne and ground half of the unit. Nitrogen gas under a pressure of 400 psig is supplied to the pressure port on the actuator in order to open the valve. In the event of pneumatic pressure failure, the valve poppets will be closed by the poppet springs. Specification pressure drop for the entire unit (airborne valve plus ground nozzle) is 25 psi at a liquid oxygen flow of 1000 gallons per minute. The pressure drop of a valve and nozzle combination that was tested was 22 psi at 1000 gpm in the fill direction.

Included in both units are position indicating switches, which by suitable circuitry indicate in the control center the position (open or closed) of the ground poppet. The airborne poppet has closed indication only. A diagram of this switch is shown in Figure 11.

5.1.2 Booster Pump Inlet Liquid Oxidizer Manifold, Part No. 7-23205. The pump inlet manifold divides the flow from the main liquid oxygen duct into two parts and distributes the flow to the booster turbopumps. This manifold is a welded assembly made of "K" Monel averaging 0.032 inch thick.

The booster pump inlet liquid oxygen manifold attaches to the 11-inch diameter main oxidizer duct at station 1175. The two pump supply legs are 7 inches in diameter, and attach to the B-1 pump at station 1185.8 and to the B-2 pump at station 1217.8.

Bosses are furnished at each pump inlet for temperature and pressure measurements during engine operation. On the series A missiles, a series of bosses were supplied on the pump inlets for the injection of helium to suppress geysering during the liquid oxidizer filling process. Use of helium injection at these points, as well as at the booster liquid oxygen disconnect valve, is a test option on the B series. The system will be deleted on the C series.

The manifold attachment points are typical of joints throughout the liquid oxygen supply system, being bolted, flanged joints. The pump inlet joints are flanged by short lugs fastened by cap screws to the pump housing, on the B series. Modified flanges not requiring the lugs are used on the C series pump inlets. Corrugated stainless steel gaskets coated with Kel-F are generally used in the oxidizer system. For leakproof joints using these gaskets, even bolt torquing, clean unscratched flanges, and a new gasket each time the joint is assembled, are requirements to be observed. Toruseal packings (hollow stainless O-rings, part number 96-58503) are used on all bosses and at the prevalve flanges. The manifold is rigidly attached to the missile thrust structure by the Liquid Oxygen Manifold Support Installation, Drawing Number 7-23224. Attachments to the thrust structure are at the following approximate stations: 1171.75, 1175.75, 1203.0, and 1206.0. The support installation is made up of the following parts and the necessary

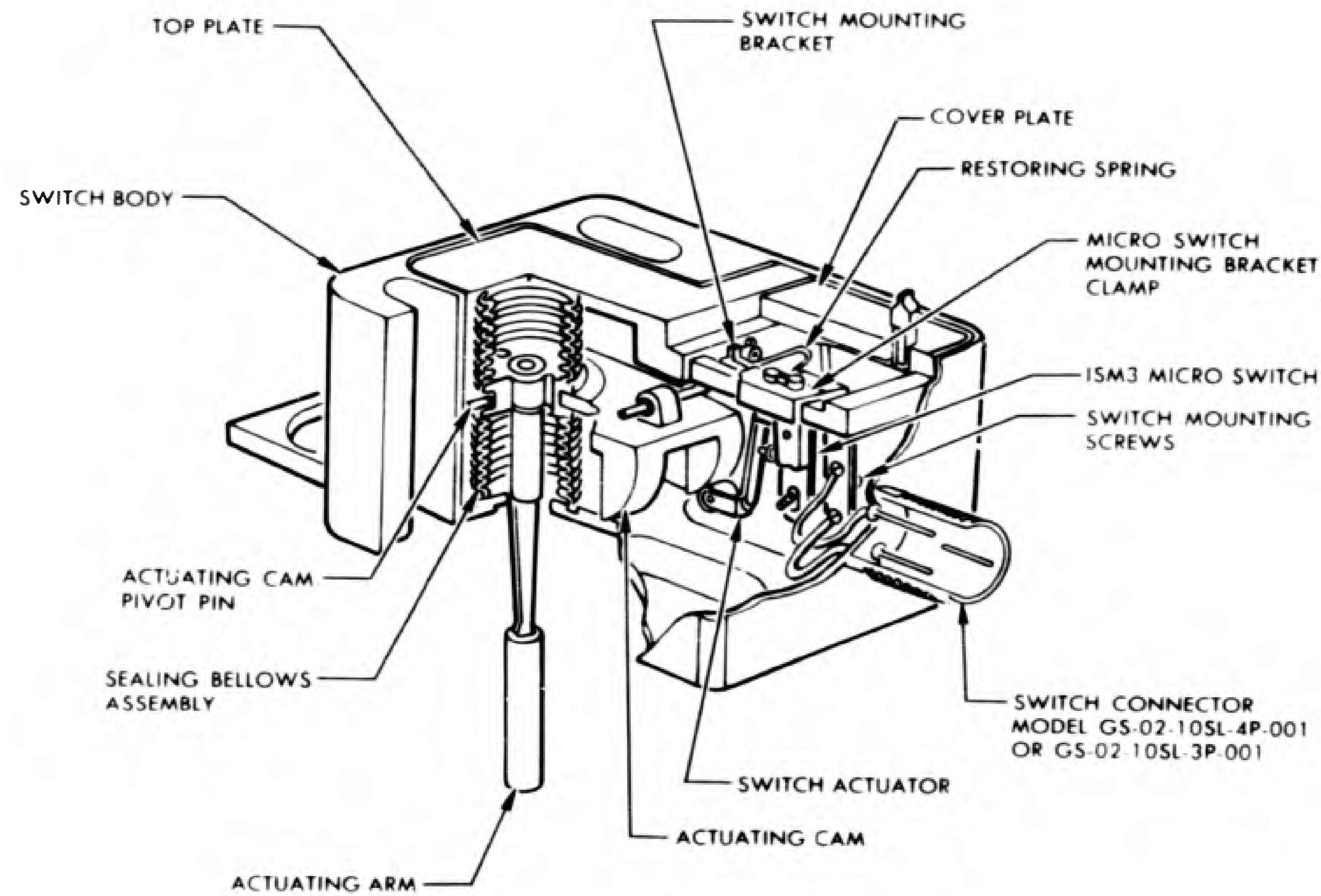


Figure 11. Liquid Oxygen Poppet Position Sensing Switch

hardware: two support assemblies, part number 7-23225; two supports, part number 7-23229, one support, part number 7-23230, and two supports, part number 7-23231.

Since the manifold is rigidly supported to the thrust structure, means must be provided to compensate for contraction under low temperature conditions, and for relative movement between the power package and thrust structure during engine operation. This flexibility is provided for by three "Omega Joints" in each of the booster pump inlet legs. See Drawing Number 7-23208 for details of the Omega joint. A single joint can take out bending but no axial movement. The combination of three in each of the manifold legs is capable of compensating for any relative motion of the pump inlet and thrust structure, and also for expansion and contraction due to temperature changes.

5.1.3 Sustainer Pump Inlet Liquid Oxygen Manifold, Part No. 7-22233. The 5-inch sustainer liquid oxygen manifold diverts flow from the main liquid oxygen duct at the disconnect valve and directs it to the sustainer pump inlet. Flexibility in this line, to compensate for contraction and expansion and vibrational movements is provided by means of 5 flexible tension carrying joints (Print No. 7-02247).

5.1.4 Spacer, Liquid Oxygen Duct (Print No. 7-23417-3). This short duct section or spacer, eleven inches in diameter and 4 inches long, is bolted to the pump inlet manifold at station 1175.0. The basic duct is made from .063 inch type 321 or 347 corrosion resistant steel with corrosion resistant steel flanges welded on. This section of ducting is proof pressure tested with water to 178 psi.

5.1.5 Valve Assembly, Booster Liquid Oxygen Disconnect (Print No. 7-02230). Figure 12 shows a perspective view of the liquid oxygen valve engaged. The aft or booster half liquid oxygen disconnect valve, which acts both to open the forward valve and to absorb various loads and misalignment to which the valve is subjected, consists essentially of a stainless steel bellows assembly and an aluminum spider assembly. The bellows assembly is comprised of a bellows welded between two flanges. The aft flange contains mounting holes for attachment to the missile booster, and the forward flange is for mechanical attachment to the spider. A flexitallic gasket is used for sealing between the spider and bellows assemblies. Excessive bellows compression is prevented by the provision of positive stops on three stainless steel rods connected between two flanges on the bellows. The spider assembly is the mating portion of the aft valve and when engaged in the forward section opens the poppet.

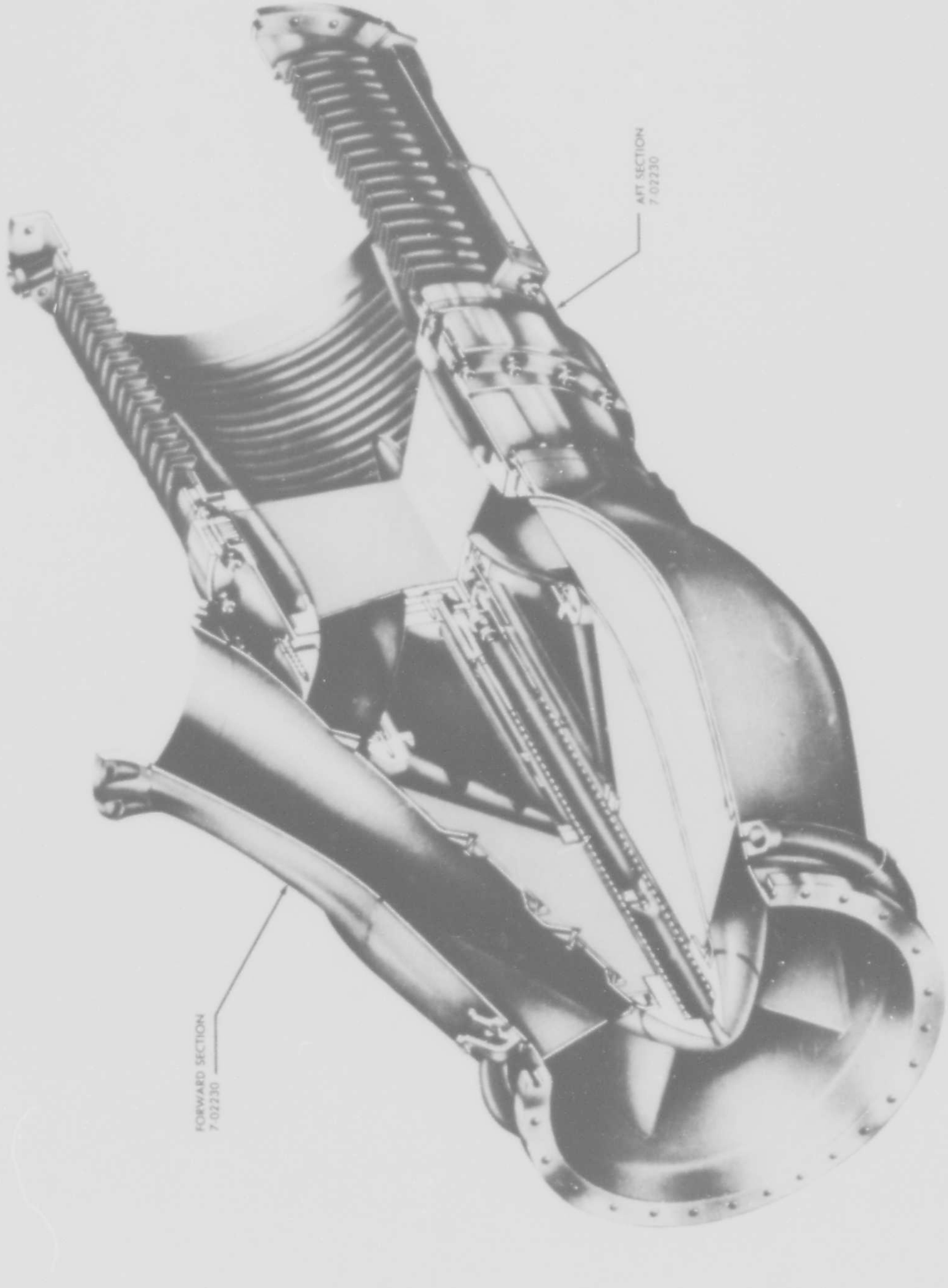


Figure 12. Booster Disconnect Liquid Oxygen Valve Assembly

The forward section consists essentially of a body assembly, ring assembly, and poppet assembly. The body assembly consists of integral guide vanes and a tube located in the center for poppet guidance, and serves as a housing for the spring assembly. The poppet assembly, which is spring loaded in the closed position, includes a teflon seal. The forward section of the valve is sealed with the mating of the teflon seal on the poppet assembly and the forward end of the ring assembly. The ring assembly is mechanically attached to the body, and this joint is sealed by a flexitallic gasket and includes an engagement seal for sealing the forward and aft section when engaged. The aft section is manually engaged to the forward section and upon initial engagement seals the two sections to prevent leakage by the mating of the engagement seal. The engagement seal is mechanically attached to the ring of the forward section and the outside diameter of the spider assembly of the aft section.

On the exterior of the forward end of the forward section of the valve is mounted a tubular manifold which is the helium injection manifold. By means of this manifold, helium is injected into the main oxidizer line to suppress geysering of liquid oxygen by increasing recirculation within the main liquid oxygen duct.

Pertinent data on the booster liquid oxygen disconnect valve (7-02230).

Flow Rates:

1. Normal operation (liquid oxygen flow aft)

   a. Valve connected, booster and sustainer outlet open at a pressure of from 67 to 130 psig

Total flow shall be	6500 gpm
Sustainer flow thru 5-inch diameter outlet	1185 gpm
Booster flow thru 11-inch diameter outlet	5360 gpm

   b. Valve disconnected, 5-inch sustainer outlet only open with a pressure of from 35 to 90 psig — 1140 gpm

2. Tank filling operation (liquid oxygen flow forward)

   a. Unit connected, 2 to 40 psig pressure — 1100 gpm

3. Proof pressure — 175 psig (min)

4. Operating pressure - the valve shall operate at a

Limit pressure unit connected	130 psig
Limit pressure after disconnection	90 psig

5. Pressure drop. Maximum pressure drop between the forward and aft flanges of the valve (connected) at 6500 gpm shall be — 4 psi maximum

   Pressure drop between the forward flange and the 5-inch diameter outlet flange (with the unit connected) at a flow rate of 1140 gpm thru the 5-inch duct shall be — 2.0 psi maximum

6. Leakage: Leakage from the unit shall not exceed the following limitations while in the specific stages of operation.

   a. With the unit connected and at any pressure from 2 to 130 psig, total external liquid oxygen leakage shall not exceed 60 cubic inches during the first two minutes of filling. After two minutes the liquid leakage shall not exceed 100 cc/min.

   b. During disconnection, but before the unit is completely separated and at 130 psig, the external leakage of liquid oxygen shall not exceed 50 cc. The poppet valve shall seat in the upper section before complete disengagement has been made with the aft section.

   c. After disconnection, the external leakage of liquid oxygen from the forward section at any pressure from 35 psig to 90 psig shall not exceed 10 cu in/min.

   d. Leakage of helium gas from the unit, when fully connected and at a gas pressure of 2 psig, shall not exceed 3 standard cu in/min. With nitrogen gas at 20 psig, leakage shall not exceed 50 cc/min.

   e. When the unit is disconnected, and the forward section is pressurized with nitrogen gas at 20 psig, leakage past the poppet shall not exceed 100 cc/min.

   f. In the mated, or demated condition, and pressurized from 0 to 20 psig with nitrogen gas, there shall be no leakage at the flanges.

7. Connection Force. The force required to connect the fore and aft sections of the valve shall not exceed 300 pounds.

8. Engagement Distance. During connection, the two sections of the valve shall engage over a maximum distance of 4.0 inches. The seal between the two sections shall be effective over this distance.

9. Disconnecting Time. The unit should be capable of disconnecting in 0.10 sec max.

10. Life. The unit cyclical life of the valve is a total of 400 on-off cycles of operation.

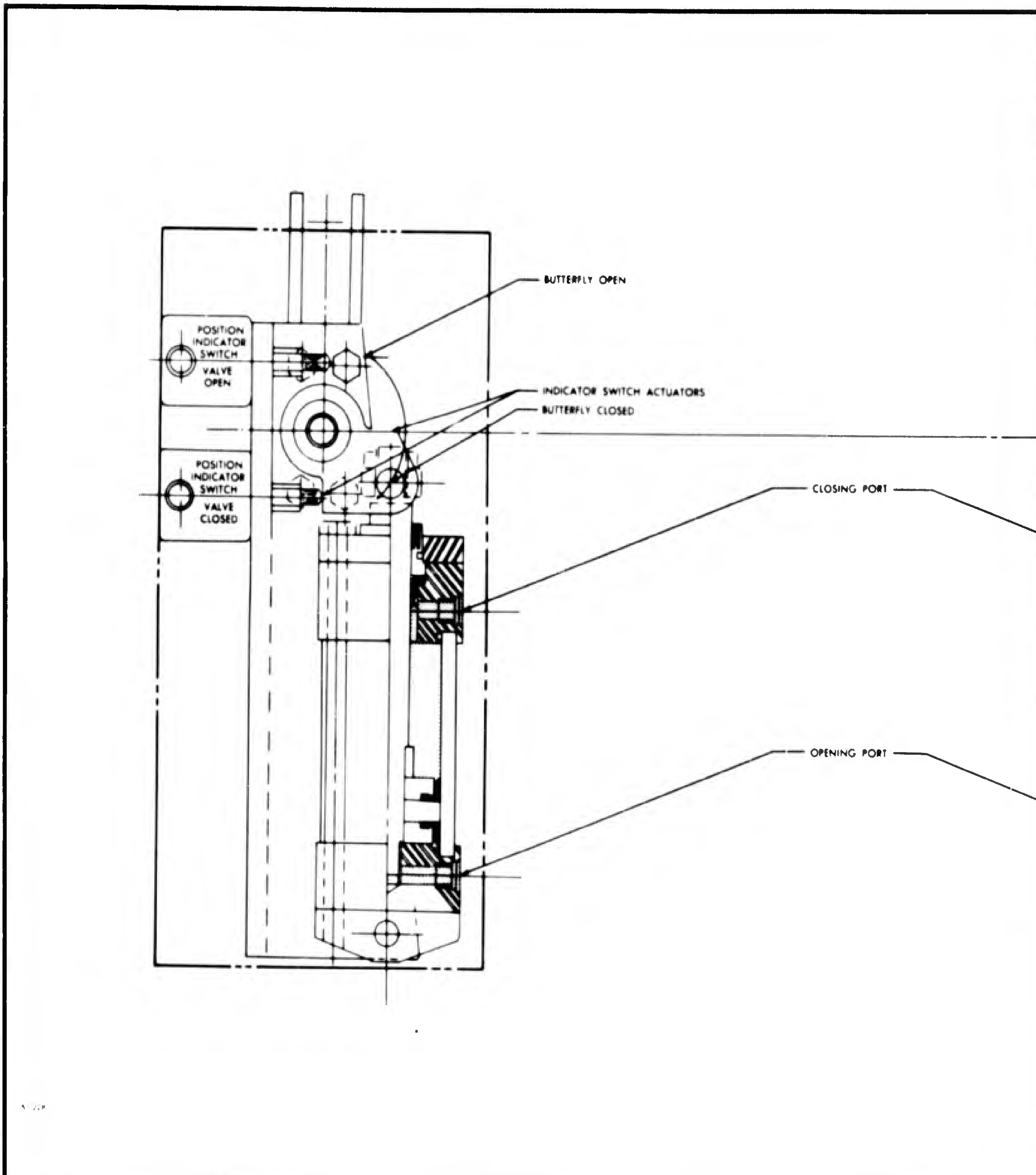
5.1.6 Liquid Oxygen Drain Line Installation, Part Number 7-76140. This installation is the main 11-inch drain duct, 17 feet 3.1 inches (207.1 inches) long, extending from station 1142.0 at the lower end to station 934.9 at the upper end. It is a light-gage corrosion-resistant steel duct, and is supported by the tank structure with mounting attachments at four places along its length (stations 1133.0, 1075.5, 1014.0, and 952.5). The drain line consists of four pipe assemblies (7-76317, 7-76318, 7-76319, and 7-76320), seam welded at the mating joints to form an integral line. To allow for temperature expansion and contraction, there are four bellows-type expansion joints in the drain line. These bellows are covered by shields or shrouds to protect them from aerodynamic heating during flight.

5.1.7 Prevalve, Part Number 7-02251 (Figure 13). The functions of this valve are two-fold: (1), to seal the tank after a certain stage of manufacture so that it can be pressurized to maintain its integrity, and (2), to act as a safety device during static firings of the missile. In this respect, it can be rapidly closed to avoid too much liquid oxygen loss in the case where engine failure results in propellant spillage. The valve is a butterfly type, designed and built by B.H. Hadley Company to Convair specifications. It is mounted between the drain line at station 934.9 and the tank outlet elbow at station 933.1. Figure 14 shows a cutaway view of the prevalve actuator.

The valve is opened and closed by a pneumatically operated, remotely controlled actuator using high-pressure (1000 psig approximately) nitrogen gas. The actuator includes a visual monitor of valve position and also two microswitches which are used for remote indication of valve position. For static firings, the remote open indication is wired into the "Missile Preparation Complete" circuit in order that the engines cannot be started until the prevalves are fully open.

Since the actuator weighs about 20 pounds and since it is not needed during flight, the actuator is removed during an actual launching countdown to save as much weight as possible. The valve is then mechanically locked in the open position, and the prevalve indication jumpered in the "Missile Preparation Complete" circuit on the control panel.

The valve body and butterfly are cast from corrosion-resistant steel, type 347 or 316, and this material is used throughout the valve parts. The butterfly seals are teflon lip-seal types. To eliminate problems with sealing, the plane of the butterfly is offset from the axis of rotation of the valve. This allows for a continuous seal and reduces


BUTTERFLY OPEN
POSITION INDICATOR SWITCH
VALVE OPEN
INDICATOR SWITCH ACTUATORS
BUTTERFLY CLOSED
POSITION INDICATOR SWITCH
VALVE CLOSED
CLOSING PORT
OPENING PORT

A.

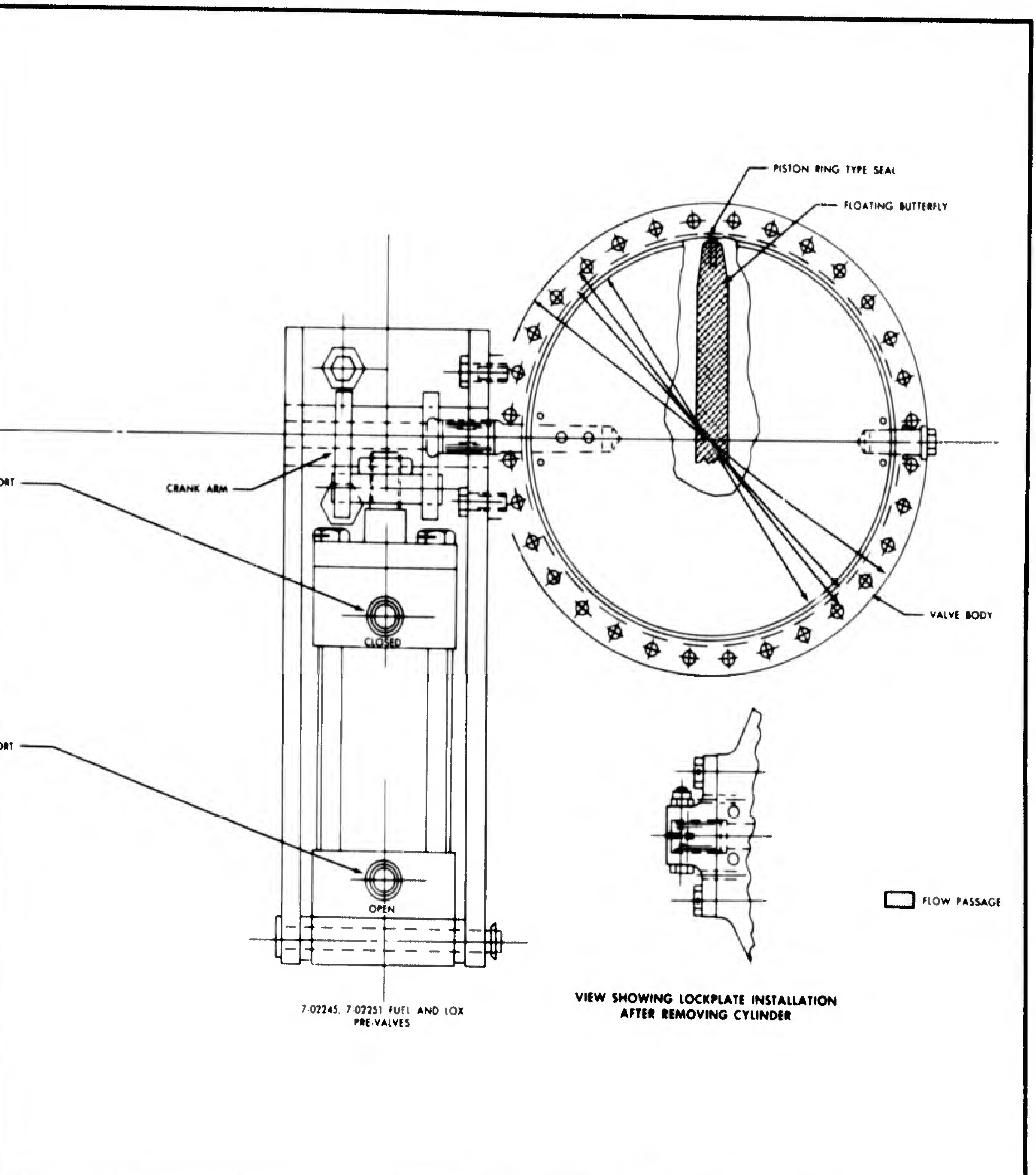


Figure 13. Liquid Oxygen Prevalve

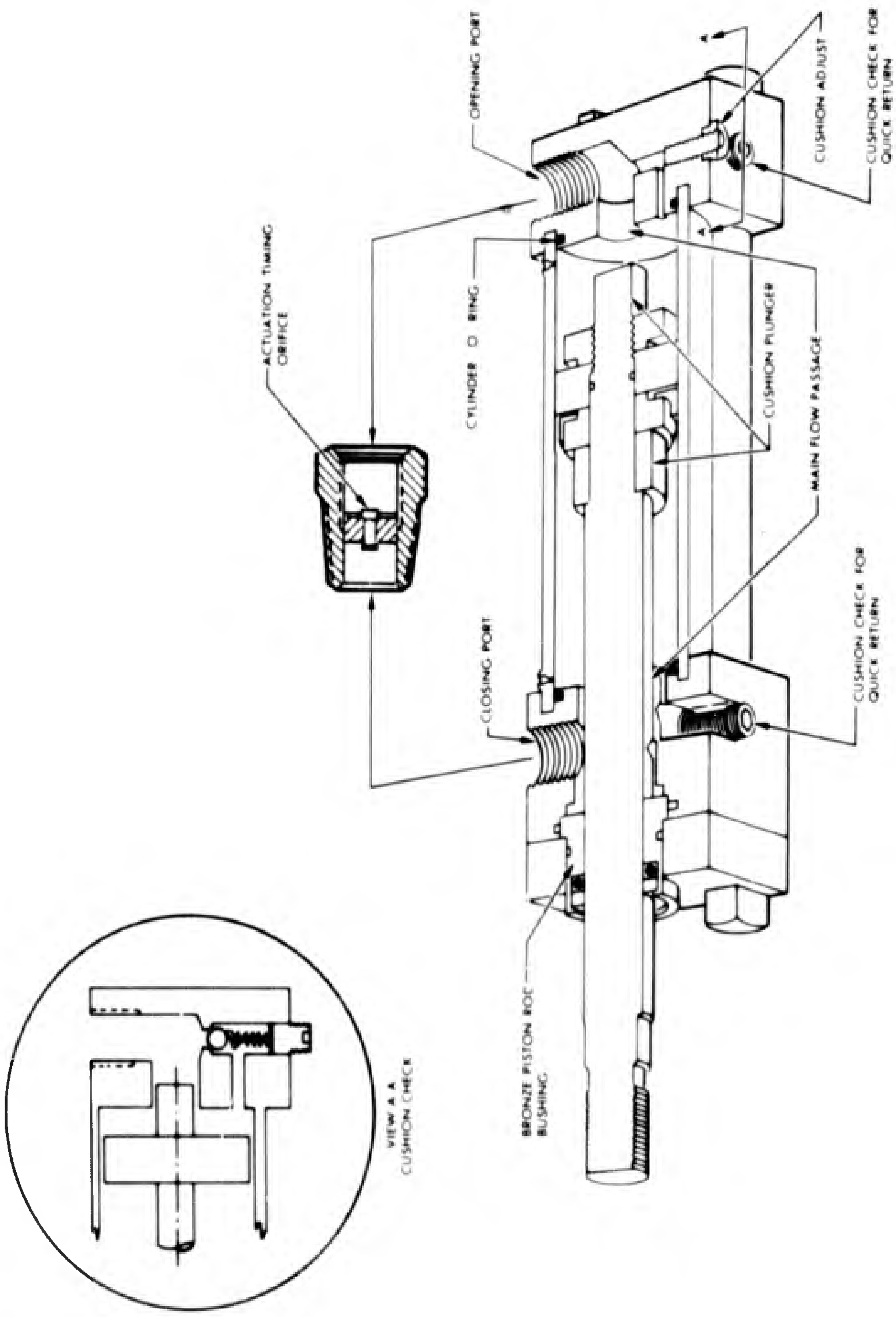


Figure 14. Prevalve High-Pressure Pneumatic Actuator

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leakage. The shaft seals are Teflon "RAV" type seals. Lubrication is achieved by dry, permanent film imbedded on moving parts by electrolysis.

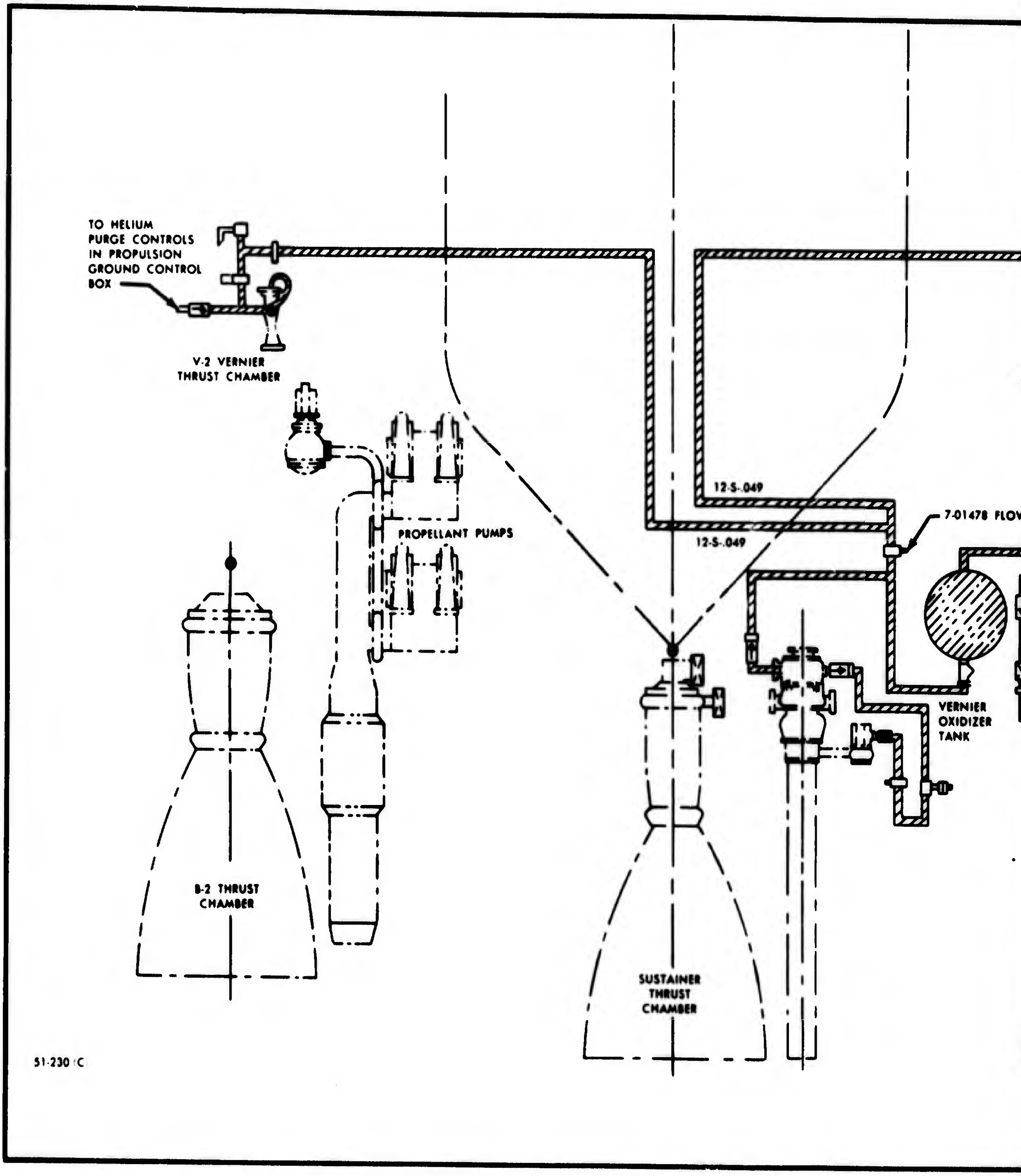
The actuator is removed by unscrewing the four cap screws which hold the actuator splined shaft which mates with the splined butterfly shaft. To lock the valve in the open position, a lock plate, furnished with the valve, is fitted on the splined shaft and bolted to the valve housing, using the same cap screws which retained the actuator. This lock plate will allow locking the valve in the open position only.

5.1.8 Seal Drain Lines, Reference Drawings 7-20201 and 7-20202. On both liquid oxygen pumps, a liquid oxygen seal and purge drain and an oil seal and purge drain are installed and routed overboard at the end of the fairing. These are 1/2-inch aluminum alloy tubes. The two liquid oxygen seal lines are tied together into a single overboard line, as are the two oil seal lines. The helium purge for the pump seals and bearings is Rocketdyne installed plumbing leading from the engine pneumatic control manifold.

5.1.9 Vent Lines, Liquid Oxidizer Start and Vernier Start (Ref. Dwg. 7-20201 and 7-20202). These are 3/4-inch stainless steel lines which are routed overboard at the aft end of the fairing from the low pressure relief valves at the main and vernier engine oxidizer start tanks. They function as bleed lines to dump liquid oxygen overboard when filling the tanks, and as vent lines when the tanks are depressurized.

5.1.10 Vernier Liquid Oxidizer Start System (Reference Drawings 7-22237). See Figure 15 for a schematic diagram of this system. The system consists of 1-inch CRES tubing from the vernier bleed on the sustainer pump to the bootstrap tee. 1-inch CRES tubing from this tee to the vernier oxidizer tank fill and check valve, and 1-inch CRES tubing from the bootstrap tee to the individual branch lines. The individual branch lines are 3/4-inch CRES tubing. The individual branch lines are of different lengths with different pressure drops. For series B and C engines, the orifices for matching vernier engines to the sustainer engine are supplied by Rocketdyne at the sustainer pump bleed port.

The vernier oxidizer start tank is installed on the inboard face and forward half of the jettison track in quadrant IV of the thrust structure. Instructions for the operation and maintenance of the vernier liquid oxidizer start tank and associated hardware are contained in North American Aircraft reports R-364P-1 and R-364P-2. Pneumatically controlled oxidizer bleed valves are incorporated into the North American Aircraft hardware on the vernier thrust chamber mounts with short overboard lines to bleed all gaseous oxygen from the oxidizer supply lines prior to starting.


TO HELIUM PURGE CONTROLS IN PROPULSION GROUND CONTROL BOX
V-2 VERNIER THRUST CHAMBER
PROPELLANT PUMPS
12-S-049
12-S-049
7-01478 FLOV
VERNIER OXIDIZER TANK
B-2 THRUST CHAMBER
SUSTAINER THRUST CHAMBER

51-230 (C)

A.

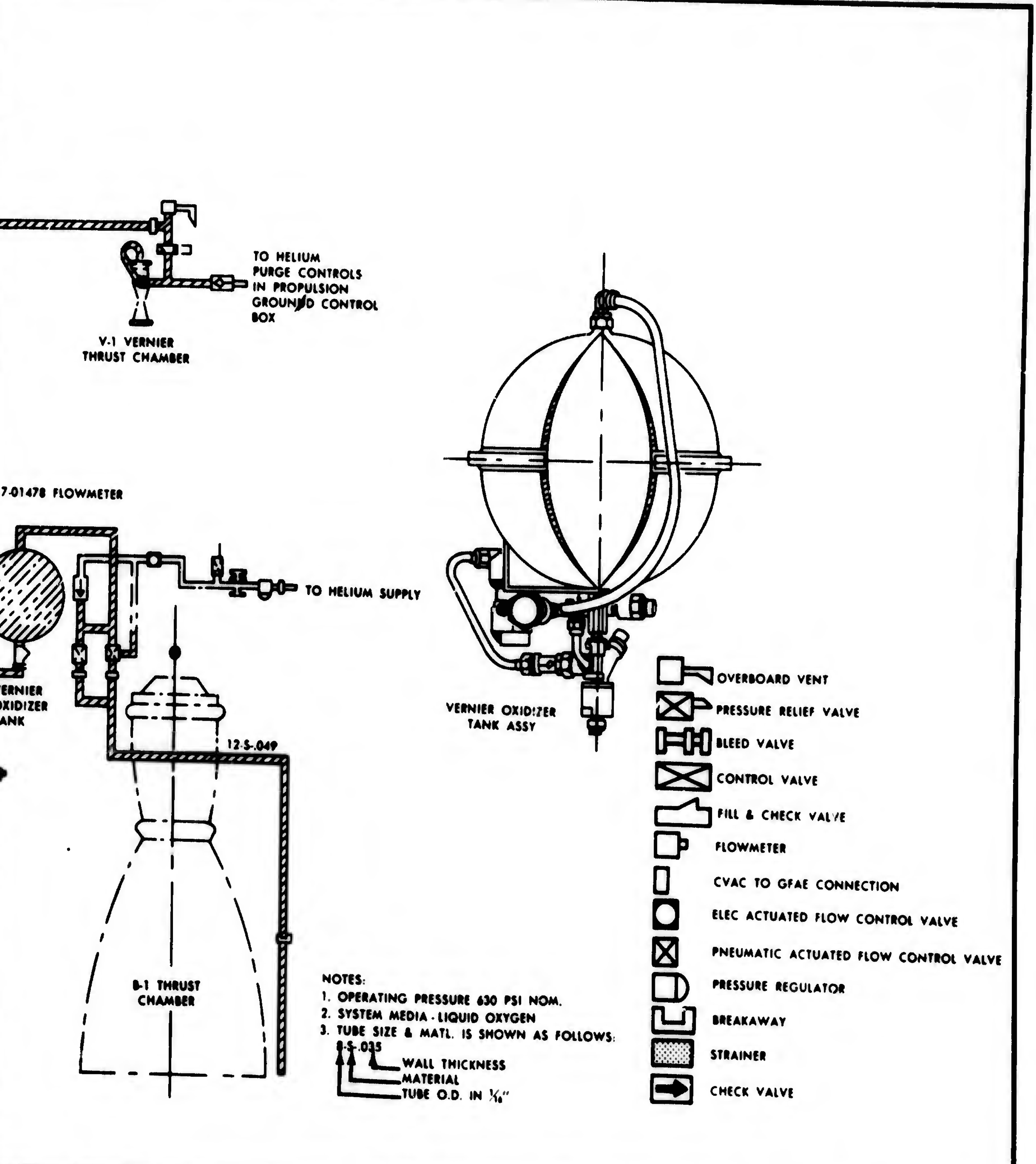


Figure 15. Vernier Engines Liquid Oxygen System Schematic

B.

The total flow of oxidizer to both vernier engines is measured by a 1-inch turbine type flowmeter in the common supply line between the bootstrap tee and the branch line.

5.1.11 Subcooled Topping System (Figure 16). The subcooled liquid oxygen topping system is used to replenish missile boil-off during countdown holds and to maintain the missile liquid oxygen system at temperatures which will assure sufficient starting NPSH to the engine pumps.

The system consists of the existing facility storage tank, a modified existing liquid oxygen tanking unit, a liquid nitrogen bath heat exchanger, and a 2-inch diameter insulated topping fill line which connects into the existing main fill line between the present liquid oxygen fill and drain valve and the new liquid oxygen main flow valve.

The liquid oxygen tanking unit (7-02222) is modified (per 7-29207) by directing the discharge flow of the variable speed pump "LC" through valve LC-2 into the topping outlet line. The throttle valve LC-1 must be closed to accomplish subcooled topping.

The heat exchanger (7-29220) has a heat transfer coil with approximately 120 feet - lineal of 2-inch diameter tubing located near the bottom of an insulated liquid nitrogen tank. As the liquid oxygen is pumped through the coil, the liquid oxygen is cooled by the evaporation of liquid nitrogen.

The liquid nitrogen tank has three hot-wire liquid detectors. The top two liquid detectors are located at approximately the two-hour and one-hour operating levels and are used to control the liquid nitrogen level. The third liquid detector is at the ten-minute operating level and turns on a red light on the liquid oxygen tanking console when the liquid level is below the detector. Two green lights indicate when the liquid level is above the one-hour and the two-hour levels respectively.

When the liquid nitrogen level falls below the two-hour level, a liquid nitrogen supply tank is pressurized causing the heat exchanger tank to be refilled. When the liquid level reaches the two-hour level, the storage tank is vented.

Insulated facility lines connect the tanking unit to the heat exchanger and connect the heat exchanger to the launcher plumbing (7-29205).

A detailed operating procedure will be published under separate cover as a C Series Tanking Procedure and will approximate the following method.

The liquid oxygen fill line, topping line, and tanking unit are chilled by opening the facility emergency dump valve, the tanking unit valves, and the storage tank outlet, the storage tank being pressurized prior to chilldown. Approximately two minutes are

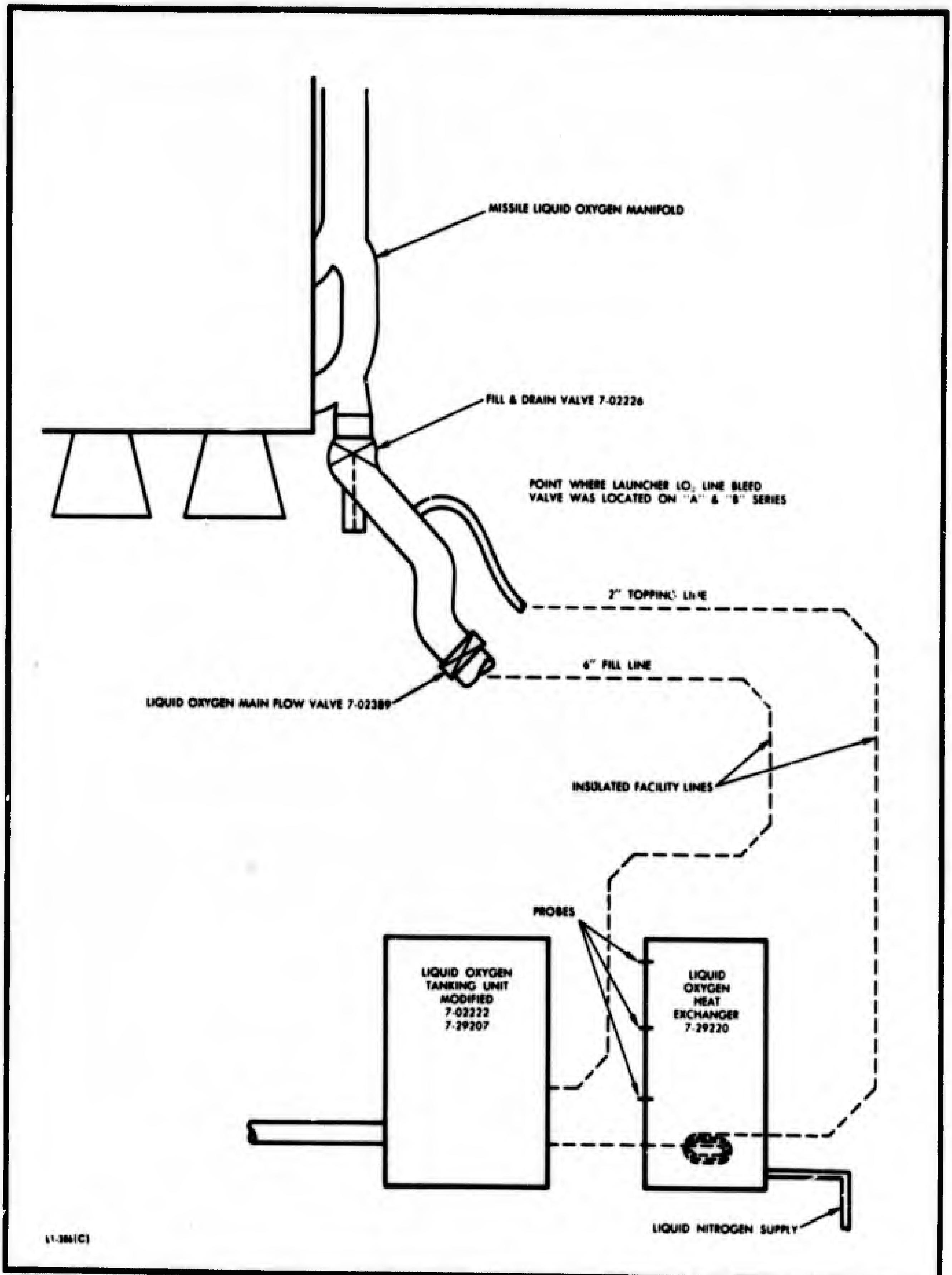


Figure 16. Series C Subcooled Topping Flow Diagram

required to chill the fill lines and to prime the tanking unit pumps. The emergency dump valve is then closed and the fill and drain valve is opened to start missile tanking with the two main liquid oxygen pumps.

Tanking to the 99.5% level will be accomplished with the main pumps at approximately 1000 gpm. The liquid oxygen level will be maintained at this point by use of the sub-cooled topping system, the amount of topping required varying between 15 and 35 gpm depending on vernier and start tank liquid oxygen bleed rate and weather conditions.

At approximately T-3 minutes, depending on the maximum topping flow obtainable at a particular test site, the topping flow is increased to the maximum rate. Liquid oxygen is brought to the 100% level between T-1 and T-0 minutes.

All tanking and topping operations are manual. Liquid oxygen loading will be monitored by the propellant utilization system which provides a meter indicating liquid oxygen level from 82% to 100.5% full and discrete point indications (lights) at 95% and 100.5% full.

5.2 PERFORMANCE, MAIN LIQUID OXYGEN FEED SYSTEM.

The aforementioned subassemblies comprise the complete oxygen supply system from the missile oxidizer tank down to the turbopump inlets and associated oxidizer systems required for missile operation. Nominal flow rates and pressure drops associated with the oxidizer supply system are as follows:

a. Total oxidizer flow in 11-inch line, 6520 gpm. The amount each pump handles is:

1. Booster #1, 2685 gpm

2. Booster #2, 2650 gpm

3. Sustainer, 1185 gpm

b. Pressure drops in the oxidizer system using nominal flow rates (Figure 17).

First Stage	Second Stage
Tank to pump B-1, 14.5 psi	Tank to sustainer pump, 8.0 psi
Tank to pump B-2, 14.5 psi	
Tank to sustainer pump, 16.0 psi	

The losses in the prevalve and in the disconnect valve are included in the above values.

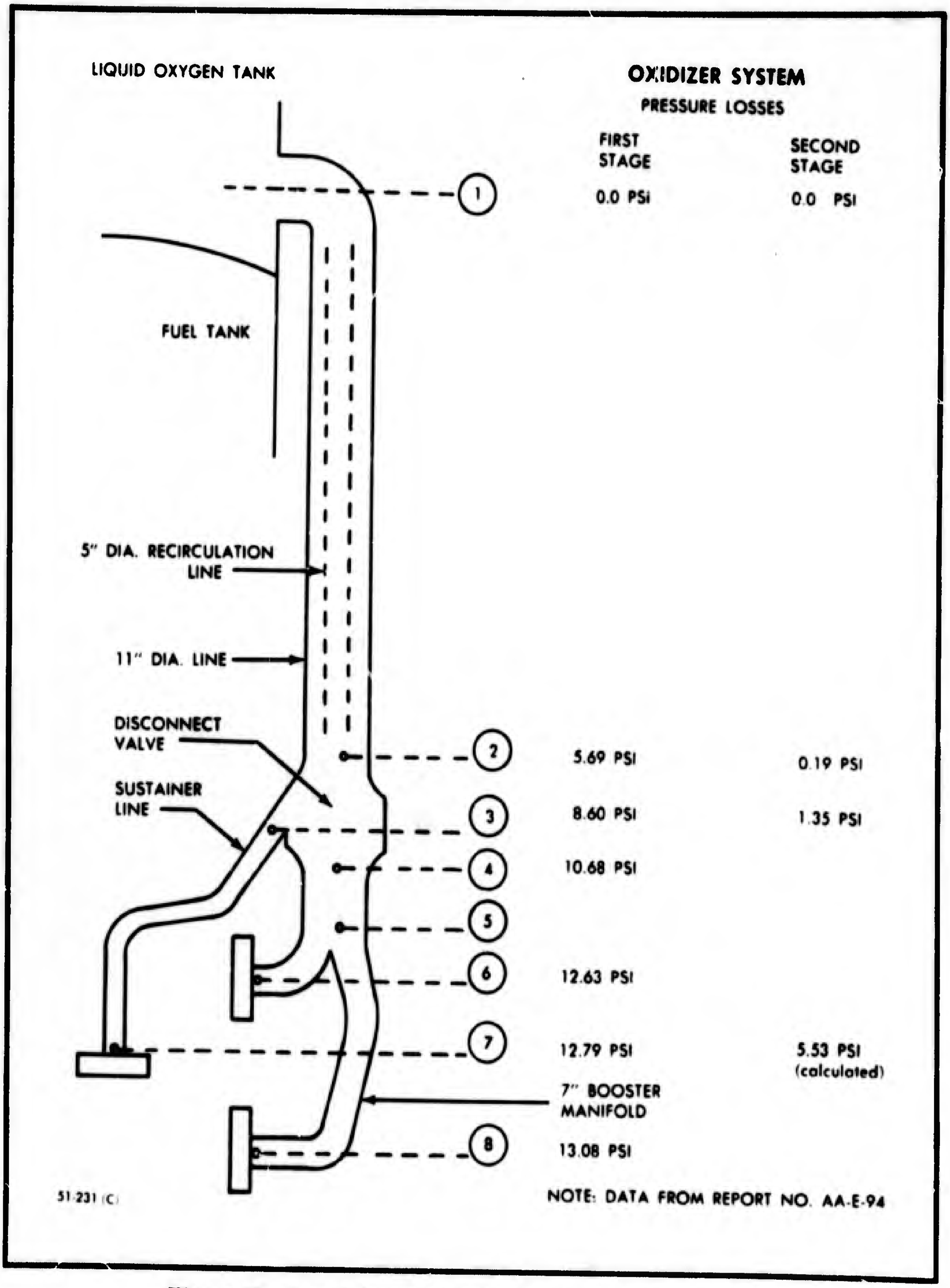


Figure 17. Liquid Oxygen System Ducting Pressure Losses

c. The fill and drain valve specification pressure drop is 25.0 psi at 1000 gpm.

5.3 PERFORMANCE, VERNIER OXIDIZER SUPPLY SYSTEM, PUMP-FED OPERATION.

The performance of the vernier oxidizer supply system for pump fed operation is as follows (Figure 4):

a. Mixture ratio 1.8 ± 2%

b. Chamber pressure, 355 psia

c. Inlet pressure at the customer connect points on the vernier engine mounts for oxidizer, 630 ± 5 psi

d. Total oxidizer flow to the vernier engines, 5.92 lb/sec

e. Individual flow to each engine, 2.96 lb/sec

f. The total pressure drop from the sustainer pump bleed port to the vernier engine customer connect point is on the order of 280 psi. This pressure loss is made up of the line losses plus the necessary calibration orifice installed in the common vernier oxidizer line. Since 630 psia oxidizer pressure is required at the customer connect point, and since the bleed pressure at the turbine outlet varies from engine to engine, no precise value of line loss plus orifice drop can be given.

5.4 PERFORMANCE, VERNIER OXIDIZER SUPPLY SYSTEM, TANK FED OPERATION.

The performance of the vernier oxidizer supply system for tank fed operation is as follows:

a. Mixture ratio, 1.8 ± 4%

b. Chamber pressure, 305 psia

c. Inlet pressure at the customer connect point for the oxidizer, 510 psia ± 5 psia.

6.0 FUEL SUPPLY SYSTEM (FIGURE 9)

6.1 GENERAL DESCRIPTION

This system consists of the necessary ducting, valving, etc., to transport the hydrocarbon fuel (RP-1) from the missile tank to the turbopump inlets. The same ducting, with the addition of a fill and drain valve, provides a means of loading the missile tank with fuel. The tank outlet elbow is located in quadrant III (Figure 1) and all of the ducting is within the thrust structure except the fill and drain valve and connecting elbow. Drawing 7-20205 is the installation drawing for this system. The following major subassemblies comprise this system.

6.1.1 Fuel Fill and Drain Valve (Figure 18). This valve, consisting of an airborne and ground half, is similar in operation to the liquid oxygen fill and drain valve. However, the physical configuration is somewhat different since the airborne unit includes an elbow which passes through the thrust structure and attaches to the side of the fuel pump inlet manifold at station 1195.8. Both the airborne valve, part number 7-02223, and the ground nozzle, part number 7-02224, were designed and manufactured to Convair specifications by Reaction Motors Incorporated, Denville, New Jersey. The operation of the valve is the same as the liquid oxygen fill and drain valve. The airborne unit contains a spring-loaded poppet valve only, and the ground nozzle incorporates the pneumatically operated actuating device which opens both the airborne and ground poppet valves. Pneumatic pressure for the operation of this valve is 2000 psig. The airborne valve contains provision for remotely indicating the closed position only, while the ground half has position indicating switches for both the open and closed positions (Figure 19). The design working pressure in this valve is 100 psig. The airborne unit weighs 26.5 pounds. The engaging travel of the ground nozzle is 1 inch and the maximum engaging force required is 100 pounds. The units may be engaged with a maximum of 1-1/2° misalignment on the vertical axis. When engaged, the maximum force acting up on the airborne valve and down on the ground nozzle during the filling operation is 1700 pounds. The force on the ground nozzle is reacted through a spring-loaded support to the launcher. A spring loaded support serves to compensate for the settling of the missile as the propellant tanks are filled. The force on the airborne valve is reacted through the Fuel Fill and Drain Valve Support Installation, Drawing No. 7-23212. This support installation consists of one link, part number 7-23254; one support, part number 7-23273; one support, part number 7-23272; one cover, part number 7-23214-7; and the necessary attaching hardware.

With the nozzle and valve engaged or disengaged, the airborne valve should have no leakage when closed. The ground nozzle should, when closed, have no leakage with 5

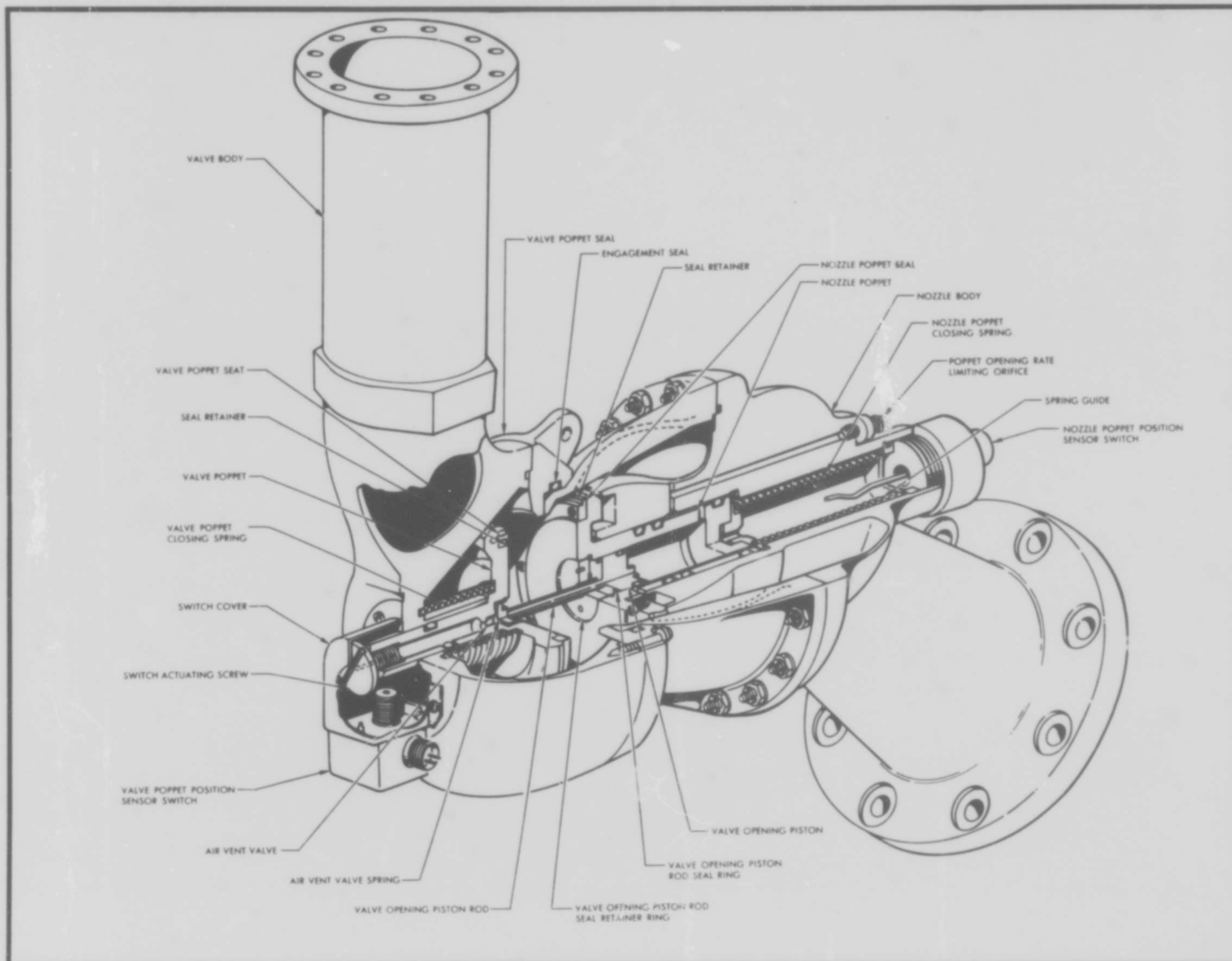


Figure 18. Fuel Fill and Drain Valve

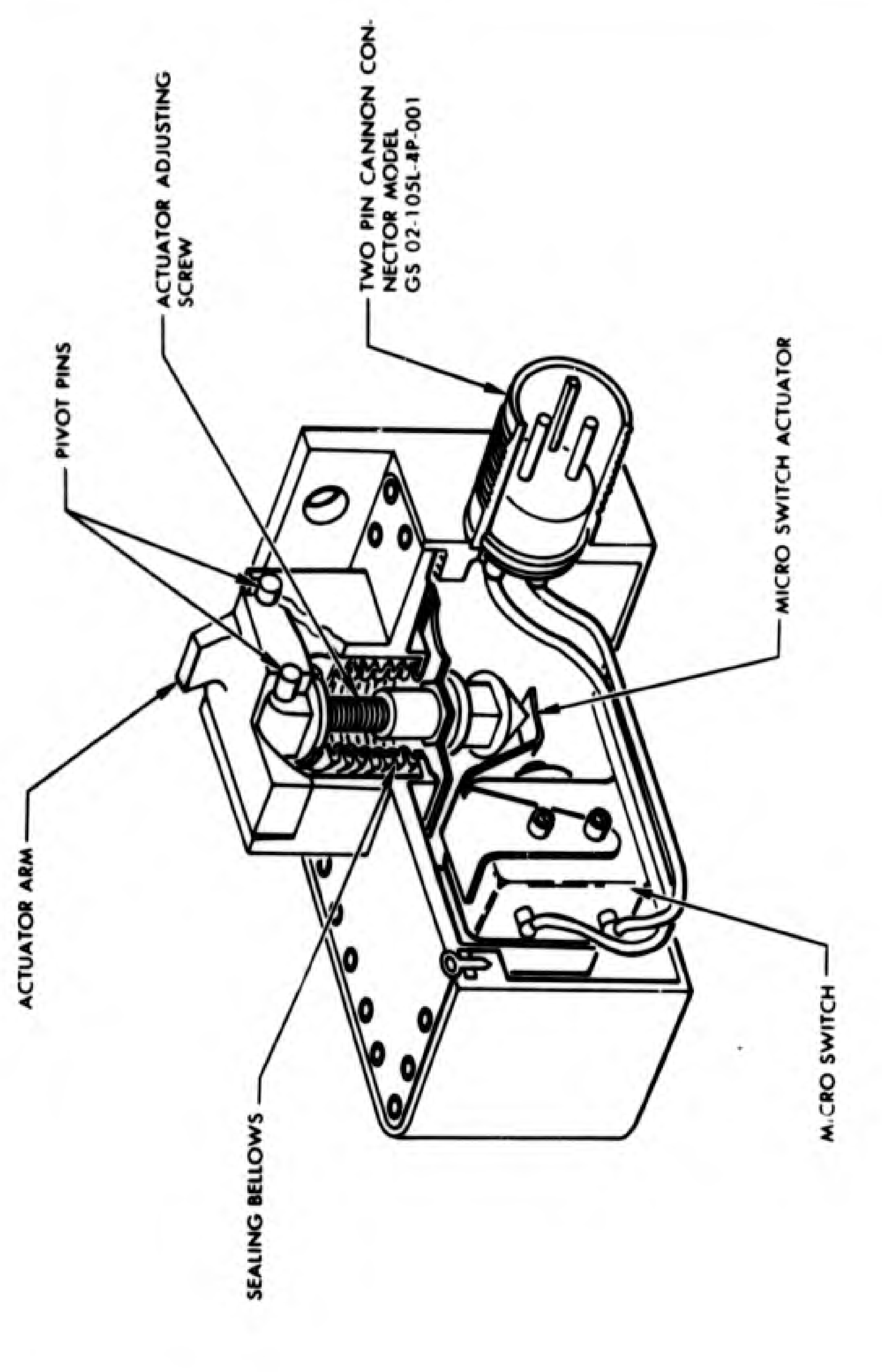


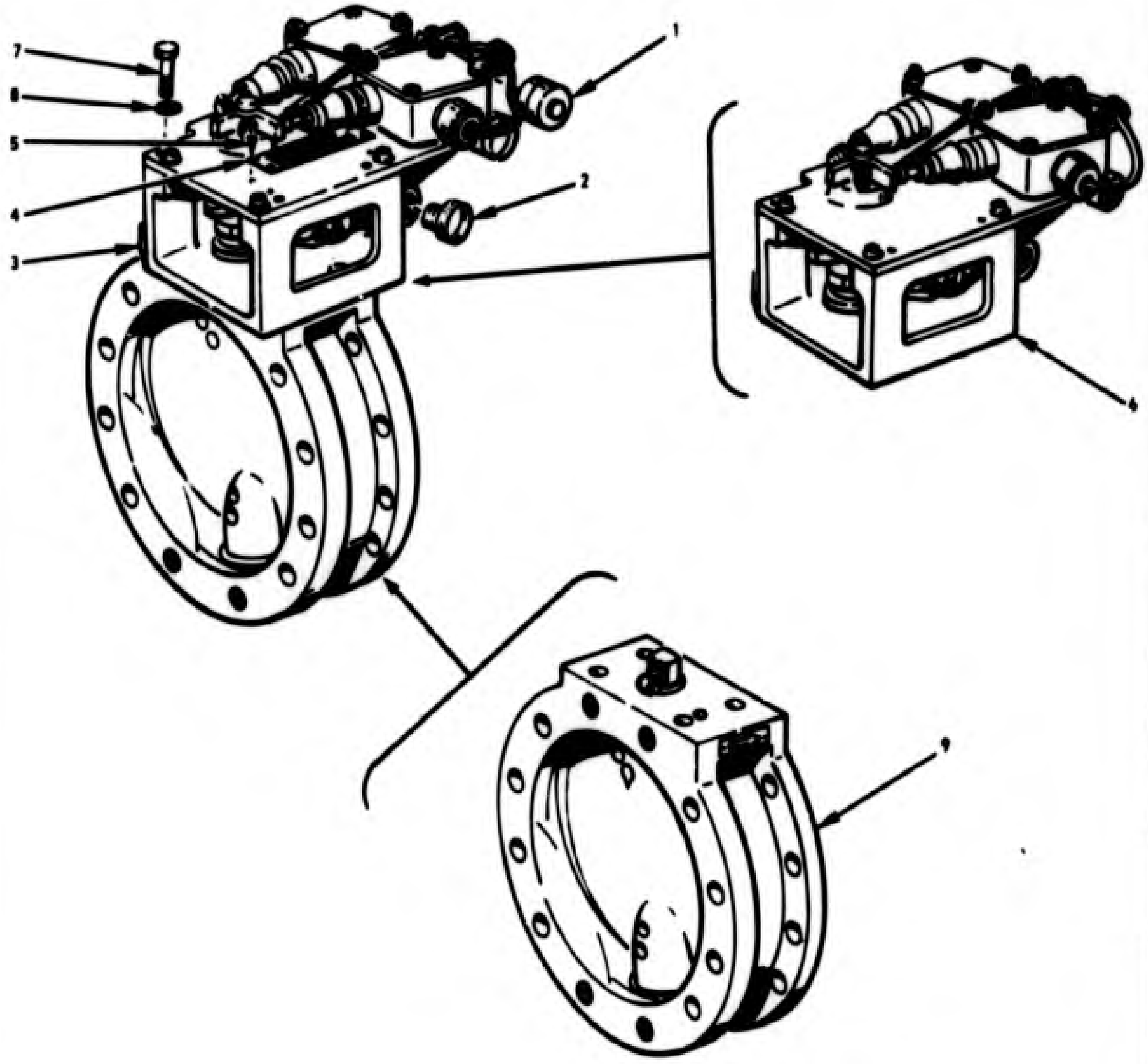
Figure 19. Fuel Valve Poppet Position Sensing Switch

psig internal pressure. However, with 100 psig internal pressure, a maximum leakage of 2 cc/min rate is allowed. During filling and draining operation with the units engaged, the maximum external leakage allowed is 3 cc/min. During the filling operation at a flow rate of 1000 gpm, the maximum pressure drop through the complete fill and drain valve is 25 psi.

6.1.2 Booster PumpInlet Fuel Manifold, Part Number 7-23204. This manifold is similar in construction to the oxidizer manifold described in paragraph 5.1b. It is a welded assembly made from K-monel averaging 0.032 inch in thickness. The manifold attaches to the fuel duct at station 1192.5 and to the two booster fuel pumps at stations 1185.8 and 1217.8; joints in the fuel system are bolted flanged joints using the same type of gasket as the oxidizer system. The pump inlets are retained by short lugs and cap screws in the same manner as the oxidizer pump inlets. The manifold distributes the flow from the 9-inch diameter main supply duct to the two 7-inch diameter pump inlet legs so that each pump receives approximately half the total flow. 3 Omega joints are located in each of the pump inlet legs to compensate for misalignment between the booster turbopumps and the thrust structure. Instrumentation bosses are provided on the manifold to measure pressures and temperatures during engine operation. The weight of the complete manifold is approximately 48 pounds. It is proof-pressure tested with water to 117 psig prior to installation. Working pressure is 75 psi maximum.

The manifold is attached to the thrust structure by the Fuel Manifold Support Installation, Drawing No. 7-23235. This support installation is designed to react all loads which are imposed upon the manifold and ducting during operation. The installation consists mainly of one support assembly, Part No. 7-23238; one support assembly, Part No. 7-23239; one support assembly, Part No. 7-23240; one support assembly, Part No. 7-23242; and one support assembly, Part No. 7-23280.

6.1.3 Booster Line Prevalve (7-inch Power Operated) Part No. 7-02287; Sustainer Line Prevalve (4-inch Power Operated) Part No. 7-02281 (Figure 20). The function of these valves are two-fold: to seal the fuel tank after a certain stage of manufacture so that it can be pressurized to maintain rigidity, and to act as a safety device during static firings of the missile. In this respect, they can be rapidly closed to prevent fuel loss in cases where engine failure results in propellant spillage. Both the 4-inch valve, model number 10576, and the 7-inch valve, model number 10577, are butterfly type valves and were designed and built by the B.H. Hadley Company. Each valve consists of two major subassemblies, the actuator and locking assembly and the valve assembly (Figure 21). The actuator and locking assembly also contains another major subassembly, the cylinder assembly (Figure 21). The valve design also incorporates a positive locking device that holds the valve butterfly assembly in an open position without the application of pneumatic pressure.



1. DUST CAP
2. SHIPPING PLUG
3. VALVE AND ACTUATOR ASSEMBLY
4. NAMEPLATE
5. NAMEPLATE MOUNTING SCREW
6. ACTUATOR AND LOCKING ASSEMBLY
7. ACTUATOR MOUNTING BOLT
8. ACTUATOR MOUNTING WASHER
9. VALVE ASSEMBLY

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Figure 20. Sustainer Fuel Prevalve

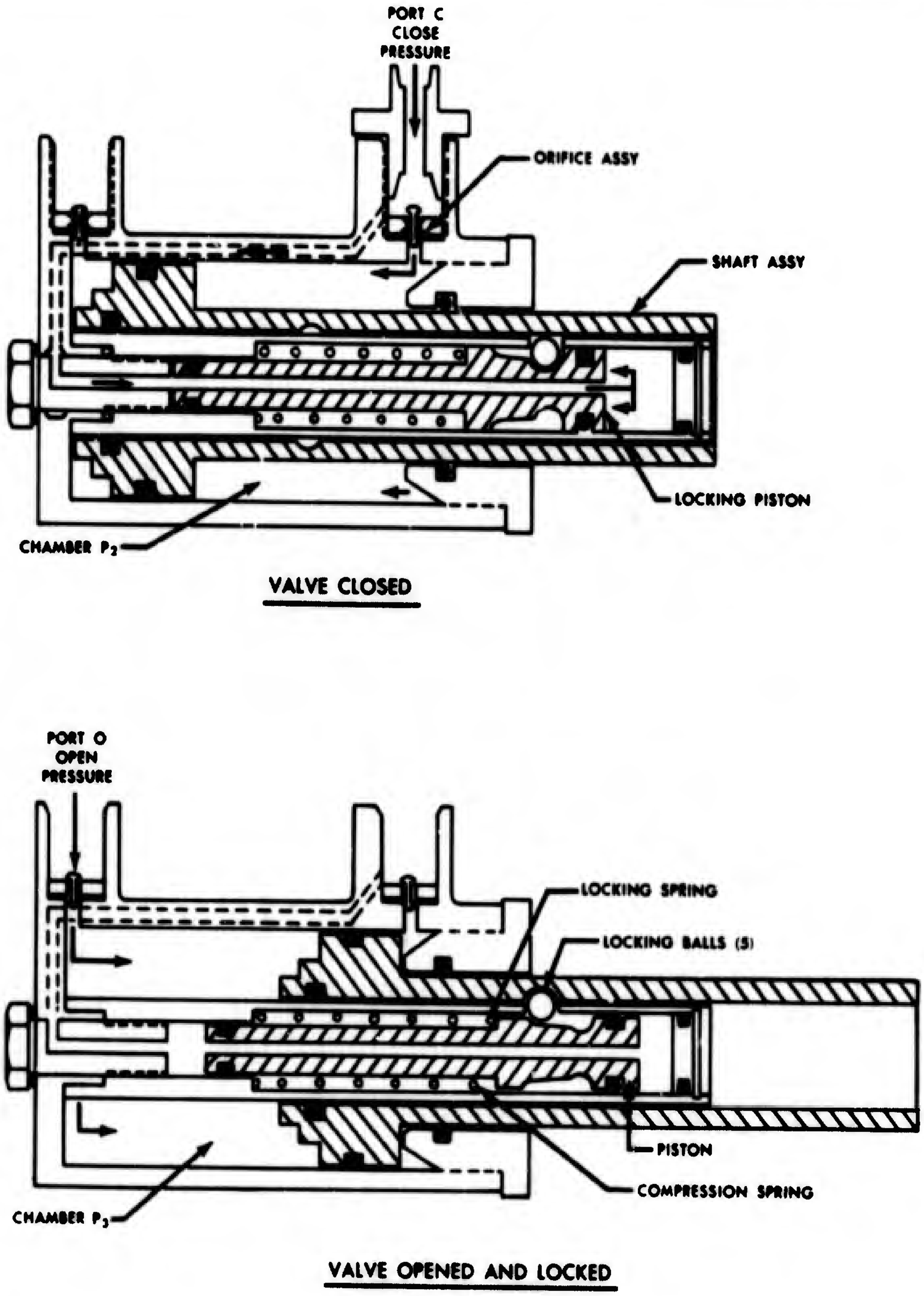

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Figure 21. Fuel Prevalve Actuator Cylinder Assembly

The 7-inch valve is mounted between the forward flange of the booster disconnect valve at station 1175.00 and the tank outlet elbow. The 4-inch valve is mounted in the sustainer fuel line between the forward flange of tube assembly 7-22232 and the outlet flange of the sustainer fuel line from the fuel tank at station 1204.5 (Figure 23).

6.1.4 Fuel Prevalve Requirements

Requirement	4-inch Valve Part No. 7-02281	7-inch Valve Part No. 7-02287
Flow rate with valve open (fuel)	735 gpm	3350 gpm
Seals against pressure (fuel)	90 psig	90 psig
Seals against pressure (helium)	10 psig	10 psig
Internal leakage with valve closed and 90 psig upstream (fuel)	5 cc/min max	20 cc/min max
Internal leakage with valve closed and 10 psig upstream (helium)	15 std cc/min max	20 std cc/min max
External leakage with valve open and pressure of 90 psig (fuel)	0 leakage	0 leakage
External leakage with valve open and pressure of 10 psig (helium)	10 std cc/min max	10 std cc/min max
Minimum proof pressure with valve open	180 psig	180 psig
Minimum burst pressure with valve open	360 psig	360 psig
Minimum proof pressure with valve closed	135 psig	135 psig
Minimum burst pressure with valve closed	225 psig	225 psig
Valve closing time	2 sec max	2 sec max
Actuator operating pressure (nitrogen)	1000 psig	1000 psig
Actuator proof pressure	1500 psig	1500 psig
Actuator burst pressure	2500 psig	2500 psig
Actuator external leakage at 1000 psig (nitrogen)	50 std cc/min max	50 std cc/min max
Locking device disengagement pressure (nitrogen)	250 psig	250 psig
Indicator switch operating voltage	18-30 vdc	18-30 vdc
Operating cycles without mechanical failure	300	300
Operating temperatures	-65°F to +160°F	-65°F to +160°F

6.1.5 Fuel Prevalve Cylinder Actuator Assembly, Close and Open Operation. Figure 21 shows a cross section of the cylinder actuator assembly in movement-to-close and movement-to-open positions. Figures 22 and 23 show the MV 500A 4-way, 2-position prevalve control valve.

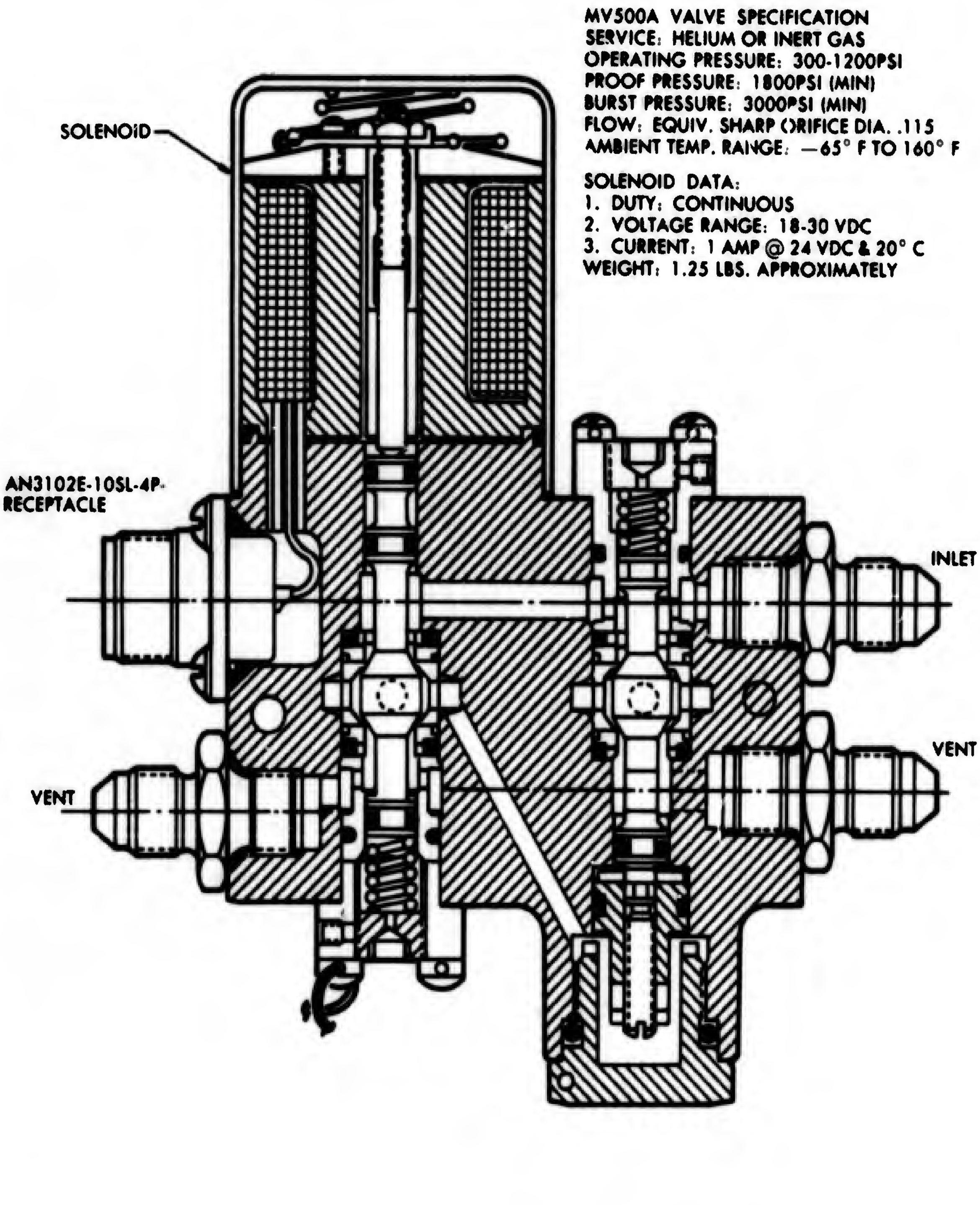

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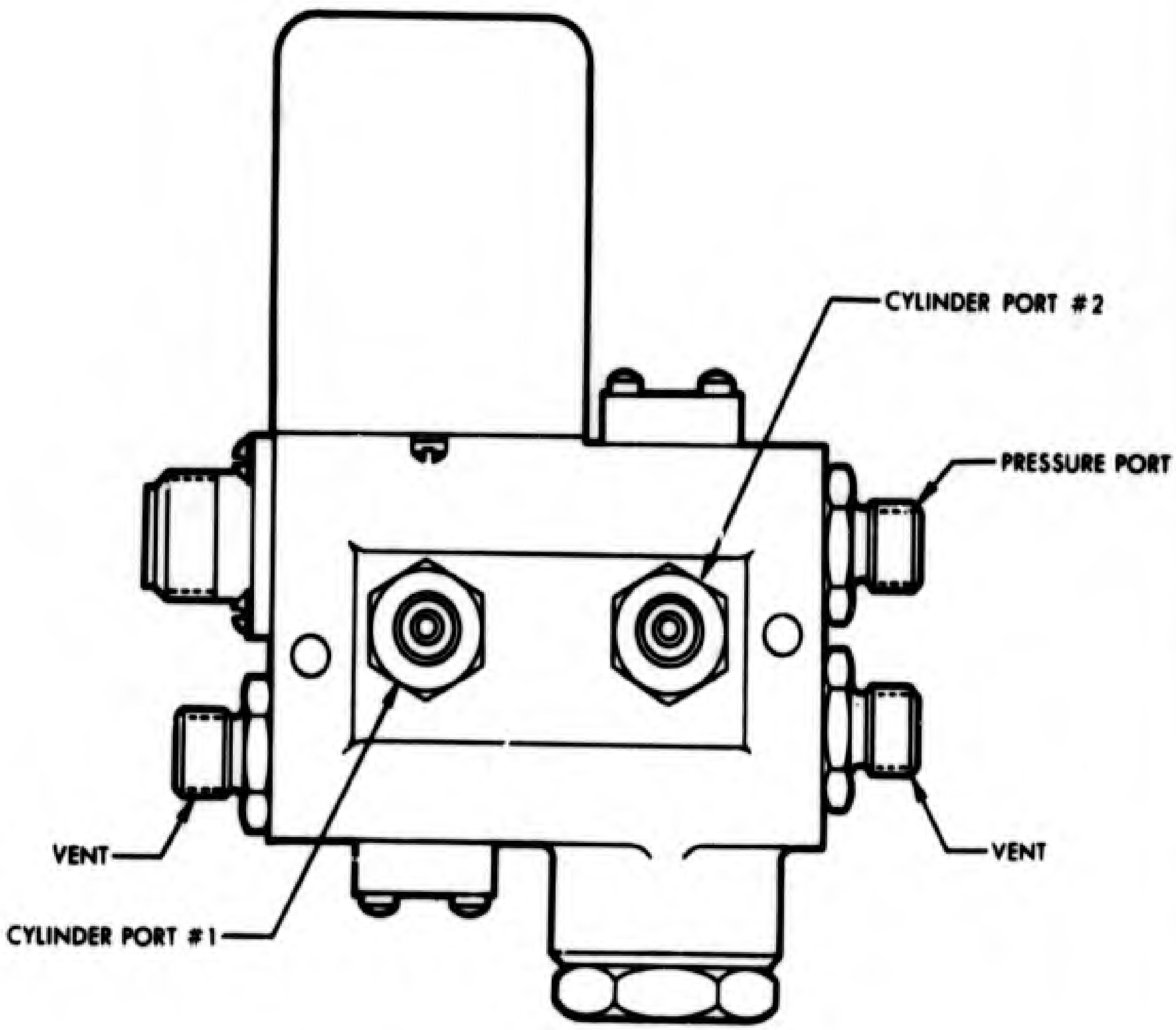
Figure 22. Fuel Prevalve Control Valve



51-235 (C)

Figure 23. Fuel Prevalve Control Valve (1/4-Tube Magnetic Selector)

a. Movement to Close Valve. With the valve in its locked "open valve" position and when the nitrogen gas pressure reaches 250 psig or greater applied at port C, the flow of nitrogen is directed through two flow paths into chambers P1 and P2. The nitrogen flows into chamber P1 through the bleed hole (shown by dotted lines in Figure 21) at a faster rate than it does into chamber P2 because of the restrictor in the orifice assembly.

When this pressure in chamber P1 reaches or exceeds 250 psig, it pushes against the face of the piston, compressing the spring mounted on the piston shaft. When the piston reaches the end of its stroke, the five detent balls are forced into their respective recesses in the piston. This disengages the piston from locking the cylinder shaft assembly, allowing movement toward the "closed valve" position.

With the buildup of pressure in chamber P2 from port C the cylinder shaft assembly is retracted toward the "open" port (O). At the completion of the retraction stroke, the butterfly assembly, which is attached to the actuator assembly by a yoke arrangement inside the valve, is closed and the valve is sealed.

b. Movement to Open Valve. A nitrogen pressure of 1000 psig is applied to port O, pressurizing chamber P3. The shaft assembly is actuated toward port C. The detent balls are pushed through the openings in the sleeve and into the recesses in cylinder shaft as it is actuated toward port C. The displacement of the balls is accomplished by a cam action of the piston as it is forced toward the cylinder shaft assembly stop by the return action of the compression spring. The combination of these movements locks the detent balls and the cylinder shaft assembly in the "open valve" position. The balls and cylinder shaft assembly remain in this position until the pressure at port C reaches 250 psig or greater. The shaft assembly then repeats the cycle described in the above section "Movement to Close Valve."

6.1.6 Valve Assembly, Booster Fuel Supply Line Disconnect Valve, Part No. 7-02229. Figure 24 shows a perspective cutaway of the booster fuel disconnect valve. The operation of this valve is the same as that of the liquid oxygen disconnect valve (refer to section on liquid oxygen disconnect valve 7-02230). The exterior valve configuration is somewhat different in that the oxidizer to the sustainer engine is diverted by way of the oxidizer disconnect valve, whereas the fuel that flows through the booster disconnect valve supplies the booster engines only, the sustainer engine fuel being supplied by a separate line.

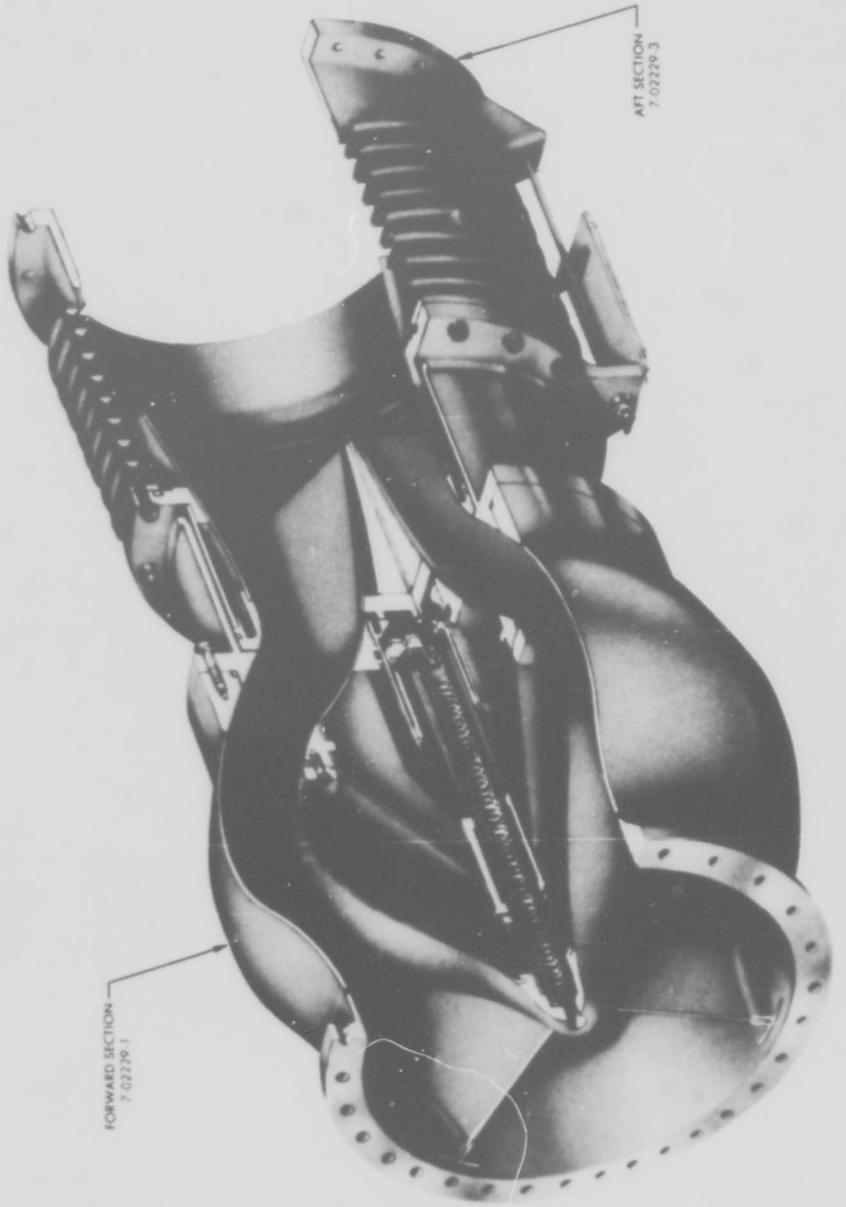


Figure 24. Booster Disconnect Fuel Valve Assembly

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Design requirements of this valve are:

Flow rate (fuel flow aft) at 70 psig	3360 gpm
Tank filling operation (flow forward)	1000 gpm at 40 psig
Proof pressure	105 psi (min)
Operating pressures	
Limit pressure - unit connected	70 psi
Limit pressure - during disconnection	70 psi
Limit pressure - after disconnection	70 psi
Pressure drop at 3360 gpm between fore and aft flanges	4.0 psi (max)

Leakage from unit shall not exceed the following:

a. When the unit is connected and the poppet open with maximum pressure of 70 psi, fuel leakage should not exceed 3 cc/min.

b. While the unit is being disconnected and with the fuel pressure at 70 psig, fuel leakage shall not exceed 30 cc/min.

c. After disconnection and with the poppet closed and with a pressure of 70 psig, fuel leakage from the forward section shall not exceed 3 cc/min and leakage from pilot valve shall be 0.

d. Leakage of helium gas from the forward section of the valve, while disconnected and with a gas pressure of 10 psig shall not exceed 3 std cc/min.

e. Leakage of helium gas from the valve when connected and with a gas pressure of 10 psig shall not exceed 3 std cc/min.

f. Connecting force to join the fore and aft sections shall not exceed 150 lbs.

g. Disconnecting force -- to demate the fore and aft sections when unit is pressurized to 70 psig, 150 lbs.

h. Engaging distance -- during connection, the two sections of the valve shall engage over a maximum distance of 3.0 inches, and the seal between the two sections shall be effective over this range.

i. Disconnecting time -- unit to be capable of disconnecting in 0.10 sec max.

A valve that has been through the flight certification test indicated a pressure drop of 1.86 psi at a flow rate of 3360 gpm at 70 psig.

6.1.7 <u>Sustainer Engine Fuel Line Assembly, Part No. 7-22232.</u> This 4-inch diameter duct assembly is comprised of straight sections, elbows and 4 flexible joint sections, Print No. 7-02250, all made of K-monel. This duct connects from Station 1206 near the apex of the fuel cone at the sustainer prevalve located along the Y-Y axis between quadrants II and III to the inlet flange of the sustainer fuel pump at Station 1226.475. Installed internally in the 7-22232-23 tube section is a 4-inch diameter flow meter for measuring the fuel flow rate to the sustainer pump. Four instrumentation bosses are provided on this duct assembly for the purpose of measuring pump inlet pressures and temperatures during engine operation.

The 7-22232 duct installation is proof pressure tested to 117 psig using water. No leakage is allowable and more than 2% yield in elongation should not be tolerated. During the proof test the ends of the ducting should be restrained to restrain the bellows assemblies. On the 7-22239-9 elbow is welded a boss for mounting of the fuel drain valve. This manual fuel drain valve, Part number 7-20205-7, is manufactured by the Interstate Engineering Company of El Segundo, California, and is a manually operated valve used to drain the residual fuel from the cone of the fuel tank.

6.1.8 <u>Vernier Fuel System Installation, Print No. 7-22236.</u> This system consists of the Rocketdyne supplied vernier fuel tank and associated Convair hardware for connecting the fuel start tank and sustainer fuel pump discharge line to the vernier engines. The spherical vernier fuel tank is located on the jettison track in quadrant II. Complete reference to the maintenance of the vernier fuel tank and associated controls is contained in Rocketdyne Report No. R364P-2. For the B series engines the orifices for matching the vernier engines to the sustainer engine are supplied by Rocketdyne at the sustainer fuel pump bleed port.

The total fuel flow rate to both engines is measured by a 3/4-inch turbine type flowmeter installed in the common line between the tee branch line connection to the vernier engines and the tee branch line from the vernier tank and turbine pump. Downstream of the turbine flowmeter the 3/4-inch fuel line tees off to two 5/8-inch lines which direct fuel to the individual chambers. The fuel supply to the APS system is provided by tapping off a 3/8-inch line from the common 3/4-inch fuel line.

The vernier fuel system is shown schematically in Figure 25.

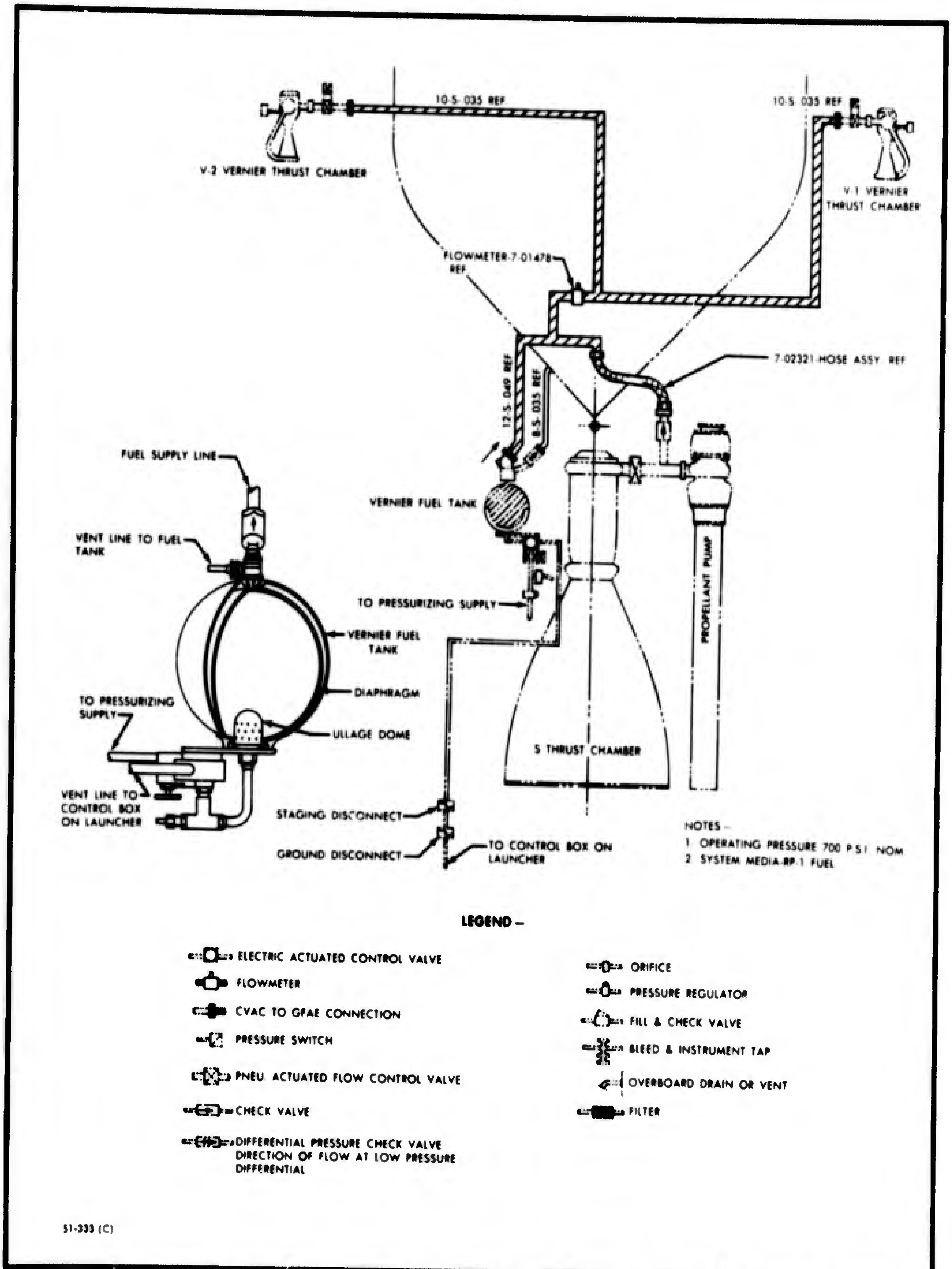


Figure 25. Vernier Engines Fuel System Schematic

6.2 PERFORMANCE, MAIN FUEL SYSTEM

The aforementioned subassemblies comprise a complete fuel supply system from the missile fuel tank to the turbopump inlets, and include the fill and drain valve through which the fuel tank is filled. Also included are various subsystems necessary for the correct operation of the missile propulsion system. Nominal flow rates and pressure drops associated with the main fuel supply system are as follows:

	Line Size	Flow Rate	Pressure Rate
B1 Pump Flow	7"	1760 gpm	9.5 psi
B2 Pump Flow	7"	1610 gpm	7.5 psi
Sustainer Pump Flow	4"	738 gpm	11.5 psi

For filling at 1000 gallons per minute, the pressure drop from the fill valve through the 7-inch duct to the main fuel tank would be on the order of 4 psi.

6.3 PERFORMANCE, VERNIER FUEL SYSTEM, PUMP FED OPERATION

The performance of the vernier fuel supply system for pump fed operation is as follows:

a. Mixture ratio, 1.8 ± 2%

b. Chamber pressure, 355 psia

c. Inlet pressure at the customer connect point on vernier engine mounts for the fuel, 630 psia ± 5 psi

d. Total fuel flow to the vernier engines, 3.28 lb/sec

e. Individual flow to each engine, 1.64 lb/sec

6.4 PERFORMANCE, VERNIER FUEL SYSTEM, TANK FED OPERATION

The performance of the vernier fuel supply for tank fed operation is as follows:

a. Mixture ratio, 1.8 ± 4%

b. Chamber pressure, 290 psia

c. Inlet pressure at the customer connect point for fuel is 510 psia ± 5 psi

Additional pertinent vernier engine flow and pressure data is indicated on the diagram, Figure 5.

7.0 PROPULSION GROUND PURGE BOX AND CONTROL BOX ASSEMBLY

7.1 GENERAL DESCRIPTION

The controls described in this section comprise the requirements for purging the rocket engine, flushing the chambers, and operation of the missile prevalves. These systems are required for servicing the engine prior to flight and before and after a missile static firing. The Propulsion Ground Purge and Control Box Assembly, Part Number 7-29117, supplies these auxiliary controls for the propulsion system. Contained in the assembly will be found the GN_2 purge controls, propellant filling valves controls, vernier engine fuel start tank diaphragm control, and liquid oxygen topping control. The controls and purge box system also includes the purge and pressure lines which are connected to the B missiles through a disconnect panel located between quadrants III and IV on the X-X axis. The lines which go to the sustainer section go through disconnects on the end of the staging tracks.

7.2 PURGE SYSTEM INSTALLATION

This installation consists of the basic Ground Control Box Assembly, Print No. 7-29117; Launcher Tubing Installation, Print No. 7-89419; Airborne Tubing Installation, Print No. 7-20441; Launcher Disconnect, Print No. 7-29136; Airborne Staging Disconnect, (in quadrant II) Print No. 7-20480; Airborne Staging Disconnect, (in quadrant IV) Print No. 7-20481. Tubing Installation Control Box Propulsion Control System, Print No. 7-20493. Schematic drawings of this system include 7-20216, Schematic Flow Diagram, and 7-65114, Electrical Control Schematic. This system supplies the inert gas purges used in static firing tests on the missile.

The ground control box is fabricated from welded steel plate. The access face is gasket sealed, thus making the box relatively water tight. The solenoid valves vent within the box, which is relieved of internal pressure through a low cracking pressure check valve. This arrangement aids in maintaining a positive pressure of inert gas within the box to prevent the entry of dirt and water. The electrical controls and the pressure regulators and gages are located on a panel at the right end of the box and are protected by a hinged cover. The physical dimensions of the box are 54 inches long, 24 inches deep, and 16 inches high. The box is mounted on brackets which are welded to the bottom of the 24-inch launcher structure in quadrant I and extending into quadrant IV.

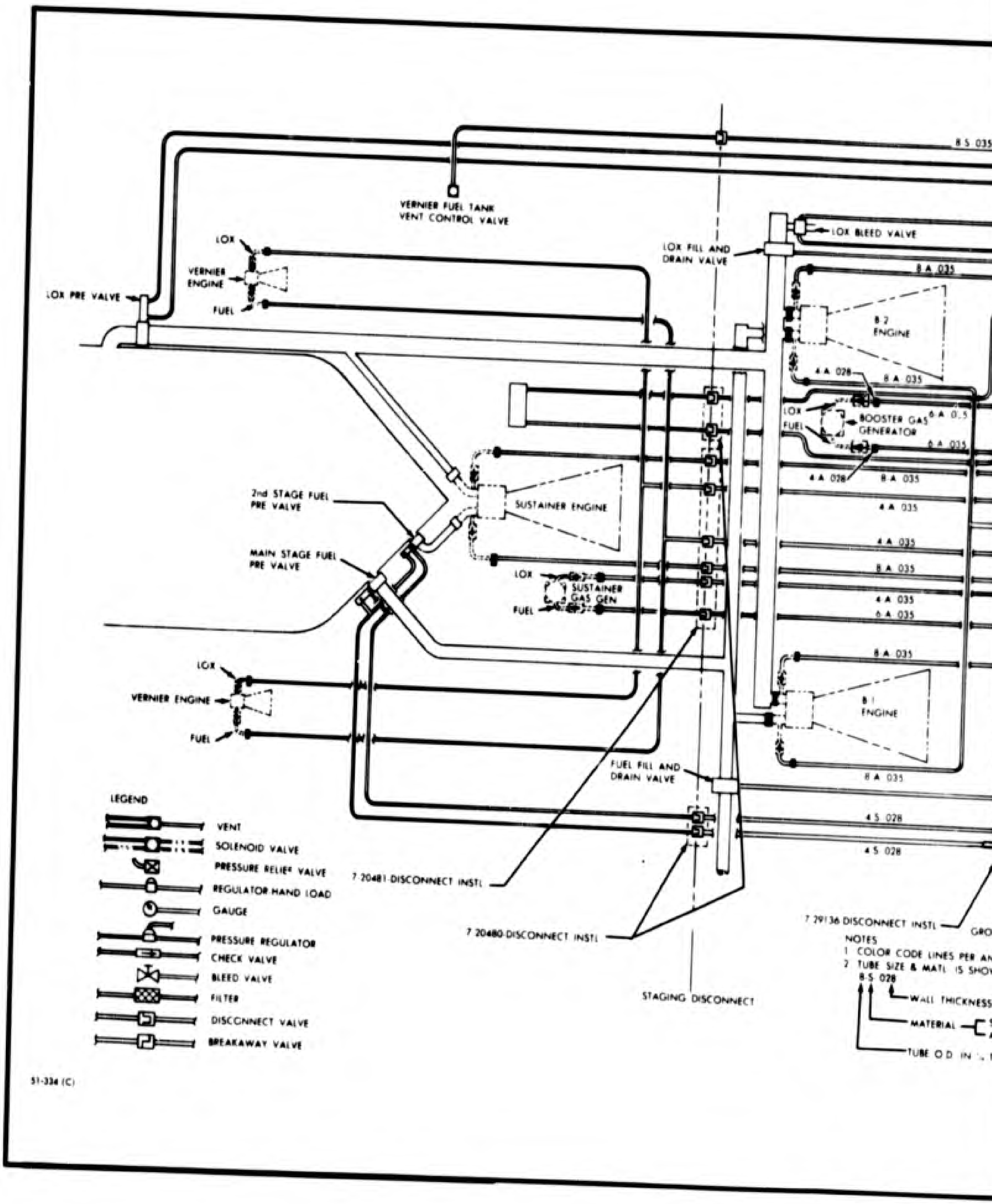
7.2.1 GN2 Purge. The GN_2 purge system (see schematic 7-20216, Figure 26) includes a filter, pressure regulator, pressure relief valves, manifold, control solenoids, and missile disconnects and associated plumbing. The GN_2 of 1500 psi to 2200 psi supply is provided from a facility stub-up and is connected to the box through a 1-inch flex hose and a 3/4-inch Aeroquip quick-disconnect coupling. The supply is then filtered through a 10-micron filter element. Purge pressure is controlled by means of a dome loaded Grove Regulator which is controlled by a hand adjusted regulator. The purge regulator should be adjusted to 1000 ± 50 psig. A pressure gage and bleed valve are incorporated in the system for adjusting the regulator. A relief valve is also provided.

The correct purge flow rates are achieved by inserting orifices in the purge lines which will produce the desired purge pressures at the specified customer connect points. The purge flow requirements as stated by the rocket engine manufacturer are as follows:

Purge	Flow Required SCFM	Orifice Size
B #1 Liquid Oxygen Injector	300-370	None
B #2 Liquid Oxygen Injector	300-370	None
S Liquid Oxygen Injector	310-380	None
V.E. #1 and #2 Liquid Oxygen Injector	95-115	#23 drill
BGG Liquid Oxygen Injector	23-26	#57 drill
SGG Liquid Oxygen Injector	9-11	#75 drill
B #1 and B #2 Fuel Jacket	300-370	None
S Fuel Jacket and Injector	180-220	#28 drill
V.E. #1 and #2 Fuel Injector	70-85	None
BGG Fuel Injector	120-145	#32 drill
SGG Fuel Injector	145-165	#24 drill

To prevent trichloroethylene or lithium chloride solution from entering the GN_2 solenoids and manifold, check valves are installed in the discharge of the purge solenoids of the sustainer and B #1 and #2 liquid oxygen and fuel purges. Also the check valve in the booster thrust chamber fuel purge line keeps inert jacket fill from entering the GN_2 solenoids and manifold.

7.2.2 Trichloroethylene Flush. The trichlor (trichloroethylene) system contains a filter, a manifold with five solenoid valves, and five check valves. The trichlor supply comes from a Rocketdyne trailer, part number 902701, capable of delivering 10 gpm at 400 psig from a 110-gallon storage source. A 1-inch flex hose and a 1-inch Aeroquip quick disconnect are used to connect the supply line to the ground purge and control box. The filter, which is inside the box, has a 175-micron element. A trichlor manifold is used to connect the supply line to the five solenoids. The check valves, part No. 7-02236 James Pond Clark circle seal type, in the trichlor solenoid discharge lines



VERNIER FUEL TANK VENT CONTROL VALVE
LOX
VERNIER ENGINE
FUEL
LOX PRE VALVE
LOX FILL AND DRAIN VALVE
LOX BLEED VALVE
8 S 035
8 A 035
B 2 ENGINE
4 A 028
BOOSTER GAS GENERATOR
SUSTAINER ENGINE
2nd STAGE FUEL PRE VALVE
MAIN STAGE FUEL PRE VALVE
SUSTAINER GAS GEN
4 A 035
6 A 035
B 1 ENGINE
FUEL FILL AND DRAIN VALVE
4 S 028
7 20481 DISCONNECT INSTL
7 20480 DISCONNECT INSTL
7 29136 DISCONNECT INSTL
STAGING DISCONNECT
NOTES
WALL THICKNESS
MATERIAL
LEGEND
VENT
SOLENOID VALVE
PRESSURE RELIEF VALVE
REGULATOR HAND LOAD
GAUGE
PRESSURE REGULATOR
CHECK VALVE
BLEED VALVE
FILTER
DISCONNECT VALVE
BREAKAWAY VALVE
51-334 (C)

A.

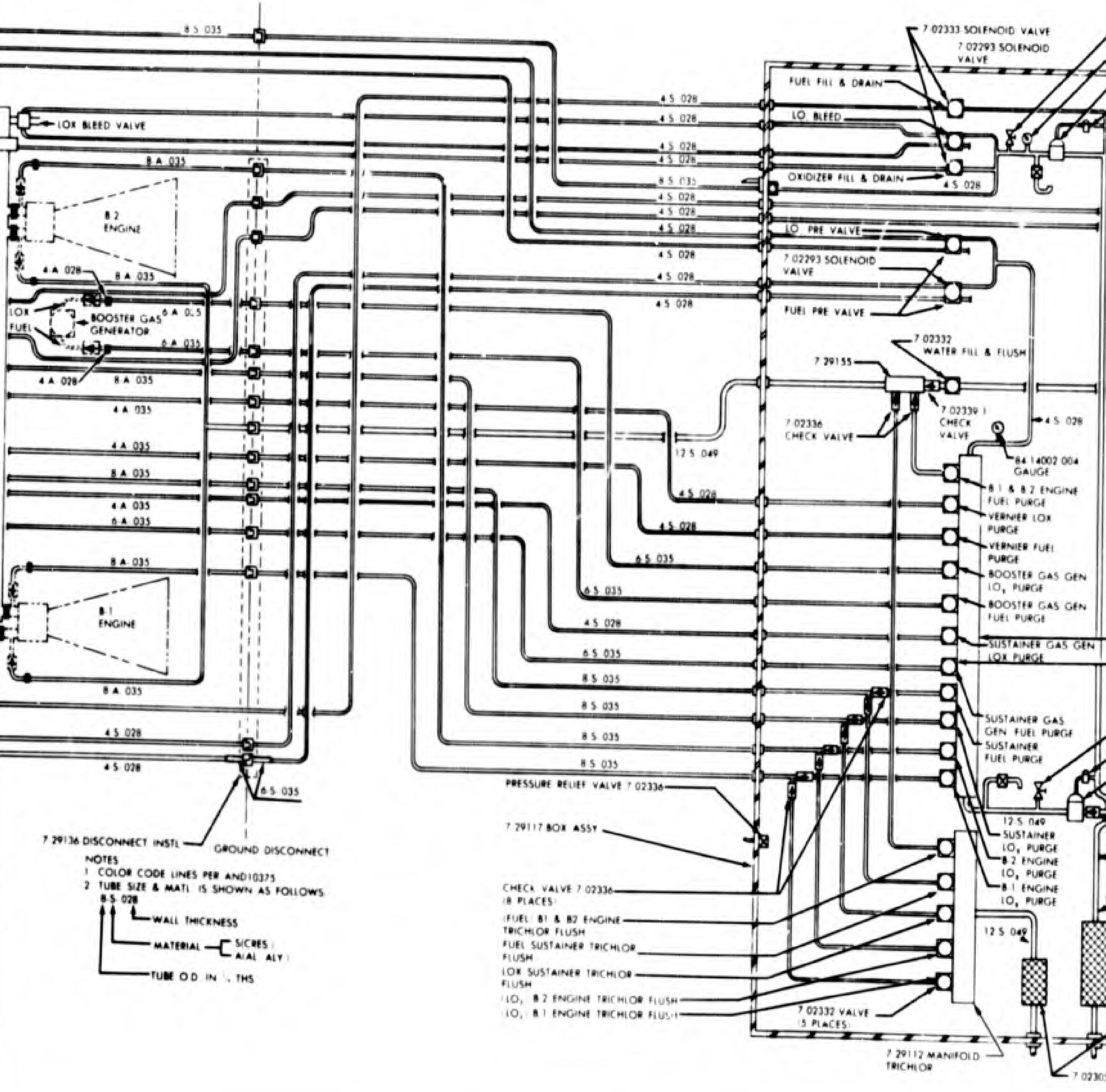


Figure 26. Ground Control Valve Installati

B.

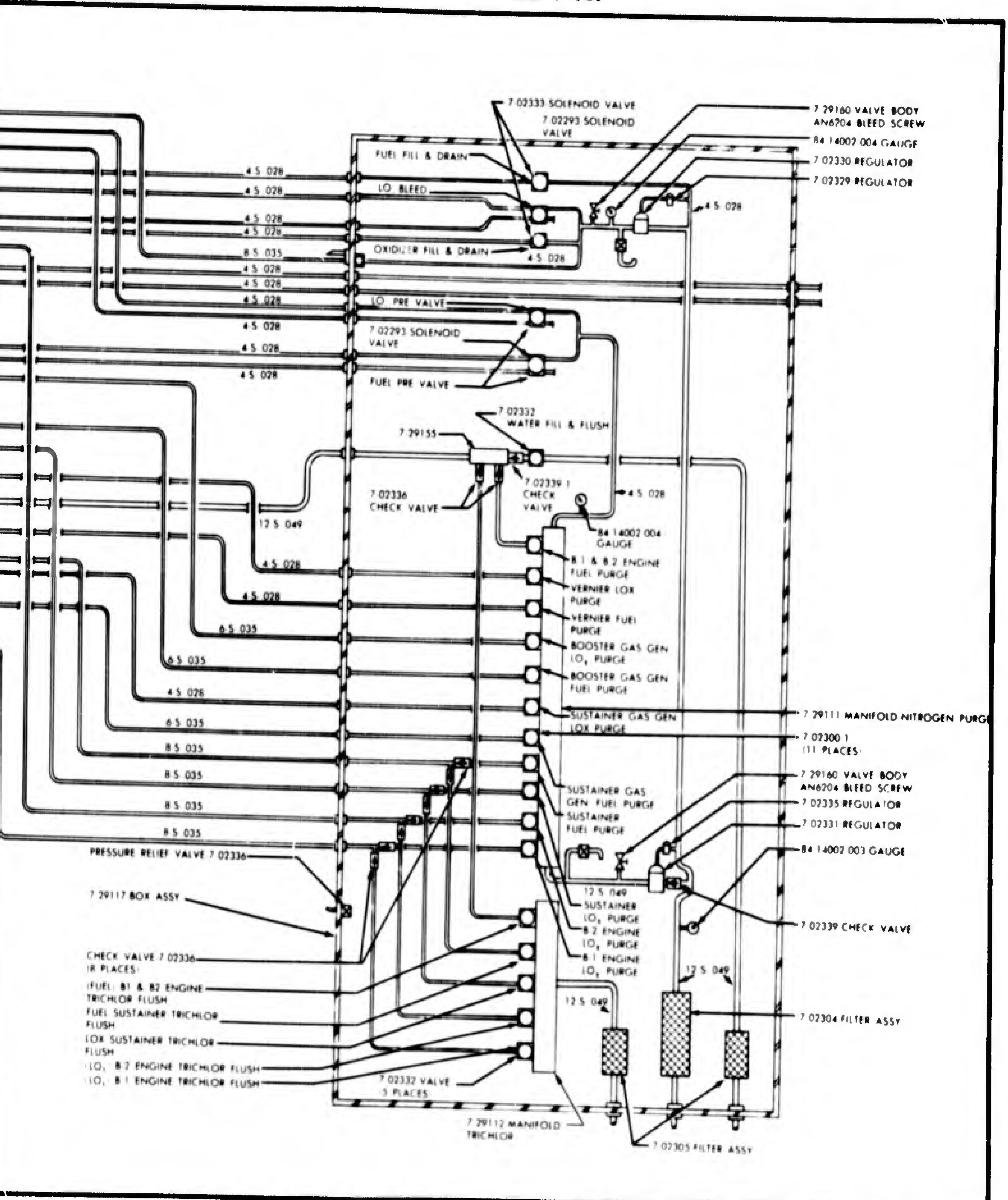


Figure 26. Ground Control Valve Installation Schematic

B.

C.

prevent the GN_2 purge from entering the trichlor system and keep the lithium chloride out of the booster thrust chamber fuel trichlor system. The trichlor flush then flows through the GN_2 purge lines to the engines.

7.2.3 Inert Fluid Lead. This system is used to fill the booster thrust chamber fuel jackets prior to a rocket engine start. This provides the inert liquid lead start required by the engine design.

A 1-inch flex hose and a 1-inch Aeroquip quick disconnect are used for the facility connection. A 175-micron filter assembly, part number 7-02305, is mounted in the box. From the filter the flushing liquid is directed to manifold, Part number 7-29112-7, then out of the manifold through a Marrotta MV-36 solenoid valve, through a Southwestern checkvalve (Print No. 7-02336), and to the booster thrust chambers.

The tubing circuits of all three fluids, i.e., lithium chloride, trichloroethylene, and GN_2, manifold into a common line, with the systems isolated by check valves, to service the B-1 and B-2 fuel jackets.

7.2.4 Auxiliary Controls. The auxiliary controls section of the propulsion ground box controls the following components:

a. Fuel fill and drain valve

b. Main liquid oxygen flow valve (located on launcher in liquid oxygen fill line, C series for topping only)

c. Liquid oxygen fill and drain valve

d. Liquid oxygen prevalve

e. Fuel prevalves, booster, and sustainer

f. Vernier fuel tank bladder cycle/vent valve.

7.2.5 Fuel Fill and Drain Valve (Figure 18). This valve is manually operated during the filling and draining operations. A 3-way solenoid valve is used to supply 2000 psig nominal line pressure to actuate the fuel fill and drain nozzle.

7.2.6 Liquid Oxygen Fill and Drain Valve (Figure 10). This valve is used in loading liquid oxygen into the missile and draining liquid oxygen from the missile, and is actuated by a 400-psig GN_2 supply. A dome loaded Grove Regulator with a Grove hand loader, a bleed valve, and a pressure gage are used to supply the operating pressure. Control of the valve is obtained by using a 3-way solenoid valve.

7.2.7 Liquid Oxygen Main Flow Valve. Upstream of the liquid oxygen fill and drain valve is the liquid oxygen main flow valve, manufactured by the Hadley Corporation. This valve is installed on Series C missiles in the missile oxidizer fill line close to the missile to isolate the long oxidizer line from the storage tank during topping procedures. This valve is actuated by a 1000-psig pressure which is tapped off the GN_2 purge system. Control of this valve is obtained by using a 4-way solenoid valve.

7.2.8 Liquid Oxygen Prevalve. Pressure for actuating the liquid oxygen prevalve is supplied at 1000 psig and is tapped off the GN_2 purge system. Temporary lines to the actuator are mounted on the outside of the missile since they will be removed, along with the actuator, before flight. Control of the prevalve is accomplished with a 4-way solenoid valve.

7.2.9 Booster and Sustainer Fuel Prevalves. Both of these valves are controlled with the same 4-way Southwestern solenoid valve MV-500A (Figures 22 and 23). The actuating pressure for the prevalves is 1000 psig and is tapped off the GN_2 purge supply system. The fuel prevalve actuators are inaccessible for removal prior to flight so will be operative even on an aborted flight. The fuel prevalve actuators have an internal locking device which will keep the prevalves open during a flight. With ground operation, the lock will engage when the valve is open and the closing pressure decreased below 150 psig. As the opening pressure then drops to zero psig after launch, the valve will be mechanically locked open.

7.2.10 Vernier Fuel Bladder Pressurization Control. A pressurizing 3-way solenoid control is included in the ground box for the purpose of expelling the gas or air from the liquid side of the vernier fuel tank. This is done by pressurizing the bladder during main fuel tanking operations. The pressurization rate of the bladder is controlled by means of a 0.032-inch diameter orifice in the pressurizing line, and pressurization is continued for a period of two minutes. This procedure prevents rapid expansion of the bladder and also limits the pressure to which the bladder is exposed to approximately 65 psig, thereby precluding possible damage to the bladder by rupture. Slow pressurization of the bladder also prevents possible premature closing of the vernier fuel start tank vent valve before the air has been completely expelled. (The pressure supply for this operation comes from the same source as for the liquid oxygen fill and drain valve.) Following this pressurization cycle the control valve is deenergized, allowing the bladder to vent and the fuel from the main tank to enter and fill the vernier fuel tank. A second pressurization and venting cycle is repeated within 15 minutes of an actual firing to ensure complete filling of the tank.

7.2.11 Electrical Controls and Purge Sequencing. The ground control box has two control panels. A local control panel on the box contains switches to operate all solenoid control valves for auxiliary controls, and purges and lights to indicate auxiliary valve positions. These controls are also used for post run clean-up, for valve checkout and troubleshooting. A remote purge panel located in the blockhouse, controls the GN_2 purge and inert fluid fill and flush solenoids. The blockhouse purge panel also has a switch which controls the 28 V DC power for the local panel and a light which indicates that all switches on the local panel are in the "off" position.

The local control panel uses rotary switches to obtain the proper sequence of the liquid oxygen and fuel GN_2 purges. For each pair of purges (BGG liquid oxygen, and BGG Fuel, etc.) the first position of the switch is "off." Turning the switch to the second position turns on the liquid oxygen purge. The third position turns on the fuel purge while continuing the liquid oxygen purge.

This switching arrangement provides a fuel purge lag upon initiation and a liquid oxygen purge lag upon termination of the purging.

Agastat time delays are used to provide proper lag times when using blockhouse controls. These time delays are set up to delay action for a desired time of about 200 milliseconds.

The B missile engine purging should perform the following functions and sequence:

1. A booster engine cutoff signal will automatically initiate the

   a. BGG liquid oxygen purge

   b. BGG fuel purge will follow (1.a) by 0.2 to 0.4 sec

   c. Booster liquid oxygen dome purge.

2. A sustainer engine cutoff signal will automatically initiate the

   a. SGG liquid oxygen purge

   b. SGG fuel purge will follow (2.a) by 0.2 to 0.4 seconds

c. Sustainer liquid oxygen dome purge.

3. A vernier engine cutoff signal will automatically initiate the

   a. Vernier engine liquid oxygen purge

   b. Vernier engine fuel purge will follow (3.a) by no less than 0.2 seconds

4. In all cases the fuel purge should be turned off 0.2 to 0.4 seconds before the respective liquid oxygen purge.

   NOTE: The sustainer and booster engine fuel jacket purges do not come on automatically at cutoff.

To perform inert fluid fill of the booster engine fuel jackets, the blockhouse manual booster engine liquid oxygen dome purges should be turned on first. The jacket fill switch is then turned on. After the jackets are noted to be full, the water fill with the liquid oxygen dome purge is turned off. The fuel purge switch on the blockhouse console is not turned on during this procedure.

The blockhouse controls for the liquid oxygen fill and drain valve, the liquid oxygen main flow valve, and liquid oxygen prevalve is located on the liquid oxygen tanking console.

The fuel fill and drain valve and fuel prevalves are controlled from the blockhouse fuel tanking console.

7.2.12 <u>Disconnect Panels.</u> There are three disconnect panels in the purge and controls system. One is a launcher rise-off panel and the other two are staging panels.

The launcher panel, located between quadrants III and IV, has 16 disconnect fittings. One fitting, the fuel prevalve opening line, has a disconnect valve that closes the line at launch to prevent the loss of GN_2.

The facility pneumatic supply to the purge box must be turned off after a launch, before the blockhouse 28 V DC power is turned off. At launch the fuel prevalves solenoid is energized and has the opening line pressurized. This line has a disconnect valve to prevent loss of GN_2 at launch. The closing line does not have a disconnect valve and will flow continuously if the supply is not stopped before the solenoid is deenergized.

The staging disconnects are located on the end of each staging track, one in quadrant II and the other in quadrant IV. Associated lines run from the launcher rise-off panel to the staging panel and include purge lines, prevalve control lines, hydraulic vent line, and APS vent line.

8.0 REFERENCES TO DRAWINGS AND SUPPLEMENTARY DOCUMENTS

8.1 CONVAIR DRAWINGS

Drawing Number	Title	Identification
7-20002-1	Propulsion System Installation	Top drawings for propulsion system. Next assembly is 7-7000 missile body assembly.
7-20203	Schematic Diagram Propulsion System	
7-20205	Fuel System Installation	Contains main fuel ducting from main tank outlet through turbopumps to thrust chambers.
7-02223	Fuel Fill Valve	This is the missileborne section of fuel fill and drain valve.
7-02224	Fuel Fill Nozzle	This is the ground half of the fuel fill and drain valve.
7-23204	Manifold Assembly	Duct assembly which directs main fuel flow to B1 and B2 turbopumps.
7-23289	Fuel System Installation Main Start	Contains fuel start system ducting and equipment between missile disconnect and turbopumps.
7-22236	Fuel System Installation Vernier Start	Contains fuel lines from pump and start tank to vernier engines.
7-22239	Tank Installation Vernier Start Fuel	Shows the mounting of the tank on the missile.
7-20204	Liquid Oxygen System Installation	Contains main oxidizer ducting from tank duct disconnect through turbopumps to thrust chambers.
7-23205-805	Manifold Assembly	Duct assembly which directs main oxidizer flow to the turbopumps.

Drawing Number	Title	Identification
7-02225	Fill Valve - Liquid Oxygen	This is missileborne half of oxidizer fill and drain valve.
7-02226	Fill Nozzle - Liquid Oxygen	This is the ground half of the oxidizer fill and drain valve.
7-22238	Tank Installation Vernier Start Liquid Oxygen	Shows the mounting of the tank on the missile.
7-20441	Purge System Installation	Controls and tubing for purging and water flushing.
7-22107-801	Vernier Rocket Installation	Installation of vernier engines on the missile.
7-23369	Drain Line Installation	Miscellaneous turbopump seal drains are shown.
7-22818	Track Installation Booster Jettison	
7-23112	Thrust Chamber Installation	Covers installation of NAA 9571-40005 (lower) and NAA 9571-40004 (upper) thrust chamber assemblies in booster section.
7-23369	Lube System Installation	Schematic shows lube system drain lines.
7-20437	Control System Installation	Pneumatic lines from turbopump control pressure manifold to thrust chamber propellant valves are shown.
7-02287	7-inch Valve-powered shutoff booster fuel (specification)	Fuel preliminary valve for emergency shutoff of fuel to booster pumps.
7-02281	4-inch Valve-powered shutoff sustainer fuel (specification)	Fuel preliminary valve for emergency shutoff of fuel to sustainer engine.

Drawing Number	Title	Identification
7-02251	Valve-powered Shut-off Main Liquid Oxygen (specification)	Liquid oxygen preliminary valve for emergency shutoff.
7-20205-7	Valve, drain-fuel tank	Hand operated valve for drain fuel from fuel cone.
7-29000	Propellant fill line installation - Launcher	Installation drawing for the main fuel and oxidizer lines on the launcher.

8.2 ROCKETDYNE PUBLICATIONS

The following Rocketdyne publications pertain to the checkout, service, and maintenance of Rocketdyne supplied equipment, and should be referred to in the course of operation of the propulsion system.

Title	Number
Engine Checkout and Operational Procedures for the MA-1 Rocket Engine	R-364P-1
Handbook of Maintenance Instructions, MA-1 Rocket Propulsion System	R-364P-2
Engine Checkout Procedures for B Rocket Engines	R 173
Handbook of Service Instructions, Ground Fuel Supply Start System	R 162
Handbook of Service Instructions, Pneu atic & Electrical Components Test Console	R 160
Handbook for Electrical Checkout Cart Assembly	R 368P
Handbook for Lubricating Servicing Unit	R 163
Handbook for Engine Power Package Dolly	R 157
Handbook for Engine Thrust Chamber Dolly	R 158
Handbook for Engine Power Package Handling Frame	R 159
Handbook for Engine Thrust Chamber Container Assembly	R 164
Handbook for Engine Power Package Container Assembly	R 165
Handbook for Rough Combustion Cutoff System	R 192

8.3 CONVAIR PUBLICATIONS

The following Convair publications pertain to the checkout and operation of the propulsion system, and should be referred to in supplementing information provided in this handbook.

Title	Number
Propellant Supply System Design XSM-65 Series Missiles	ZK-7-015
Preliminary Factory Checkout Procedure for XSM-65B Missile Propulsion System	ZI-7-087
Test Data Requirements, Propulsion Systems XSM-65 Series Missiles	ZK-7-016 TN
Handbook for Operation of Fuel Transfer Unit	ZK-7-032
Handbook for Operation of Liquid Oxygen Transfer Unit	ZK-7-033
Electrical Handbook - Propulsion System XSM-65B Missile	ZK-7-048
Operational Checkout Requirements Handbook, Series B Missile	ZK-7-041 TN Revision A

9.0 OPERATING INSTRUCTIONS

9.1 GENERAL

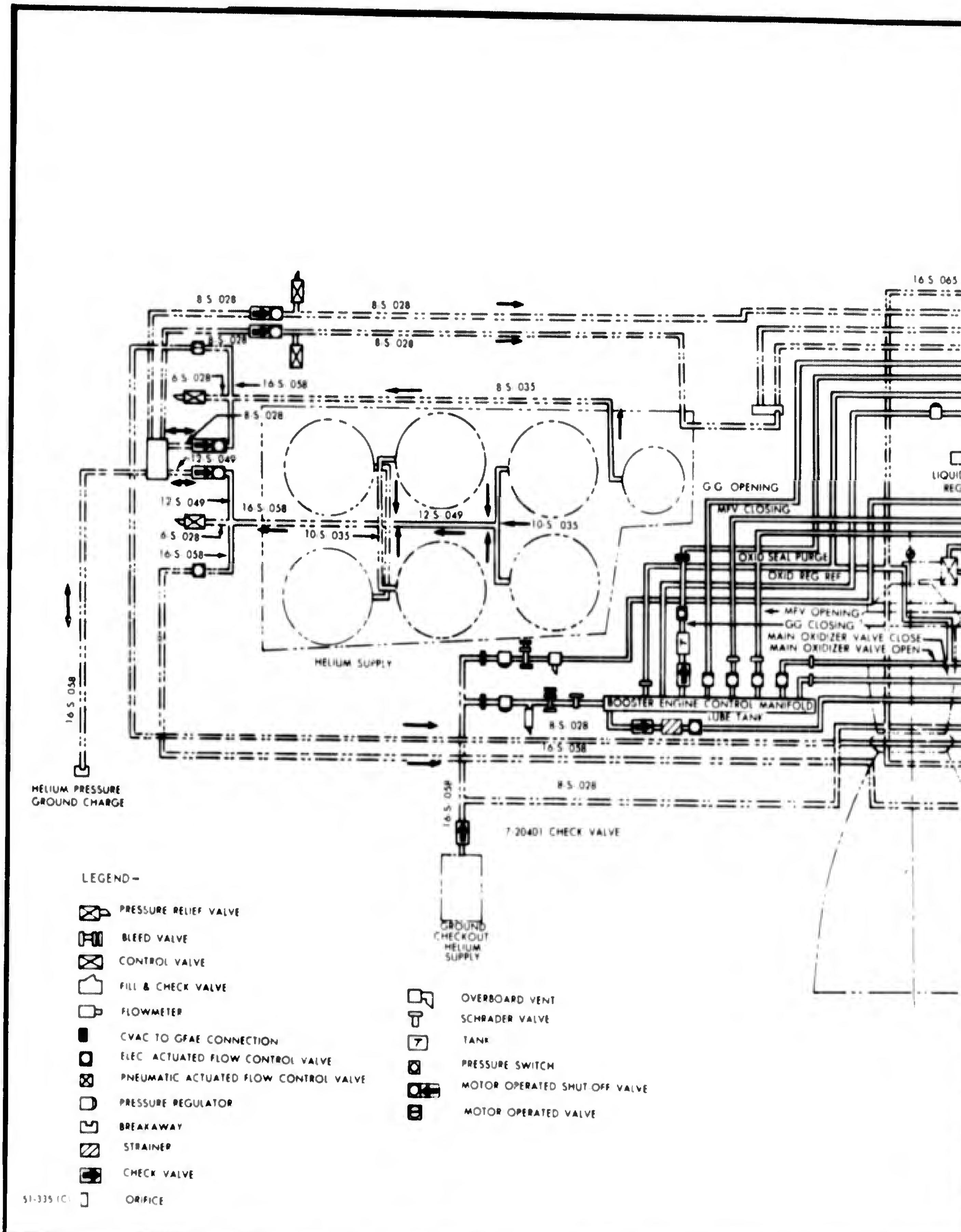
The actual operation of the XSM-65 Series B propulsion system is deeply interrelated with the associated systems which comprise the complete missile, and it is considered to be beyond the scope of this handbook to attempt to detail the many steps involved in preparing the missile for firing and performing a firing.

These details are considered to be adequately treated in the countdown sheets which are generated for this purpose. The countdown sheets are patterned individually to accommodate the various test sites and missiles, and are intended to fully integrate the operations of all the systems.

Figure 27 is a schematic of the helium system engine controls.

Figure 28 is a block diagram which outlines the various prestart functions which require completion before a missile is launched, together with the sequence of operation of the rocket engine. Figure 29 is a block diagram showing the propulsion system shutdown functions.

Several requirements exist for properly checking out the propulsion system following erection of the missile in the launcher. Refer to ZK-7-041, Revision A, and ZI-7-087 for these requirements.


8 S 028
8 S 028
8 S 028
8 S 028
6 S 028
16 S 058
8 S 035
8 S 028
12 S 049
12 S 049
16 S 058
12 S 049
6 S 028
10 S 035
10 S 035
16 S 058
16 S 058
16 S 065
HELIUM SUPPLY
G G OPENING
MFV CLOSING
OXID SEAL PURGE
OXID REG REF
MFV OPENING
GG CLOSING
MAIN OXIDIZER VALVE CLOSE
MAIN OXIDIZER VALVE OPEN
BOOSTER ENGINE CONTROL MANIFOLD
LUBE TANK
8 S 028
16 S 058
8 S 028
16 S 058
7-20401 CHECK VALVE
HELIUM PRESSURE
GROUND CHARGE
GROUND
CHECKOUT
HELIUM
SUPPLY
LEGEND -
PRESSURE RELIEF VALVE
BLEED VALVE
CONTROL VALVE
FILL & CHECK VALVE
FLOWMETER
CVAC TO GFAE CONNECTION
ELEC ACTUATED FLOW CONTROL VALVE
PNEUMATIC ACTUATED FLOW CONTROL VALVE
PRESSURE REGULATOR
BREAKAWAY
STRAINER
CHECK VALVE
ORIFICE
OVERBOARD VENT
SCHRADER VALVE
TANK
PRESSURE SWITCH
MOTOR OPERATED SHUT OFF VALVE
MOTOR OPERATED VALVE
51-335 (C)

A.

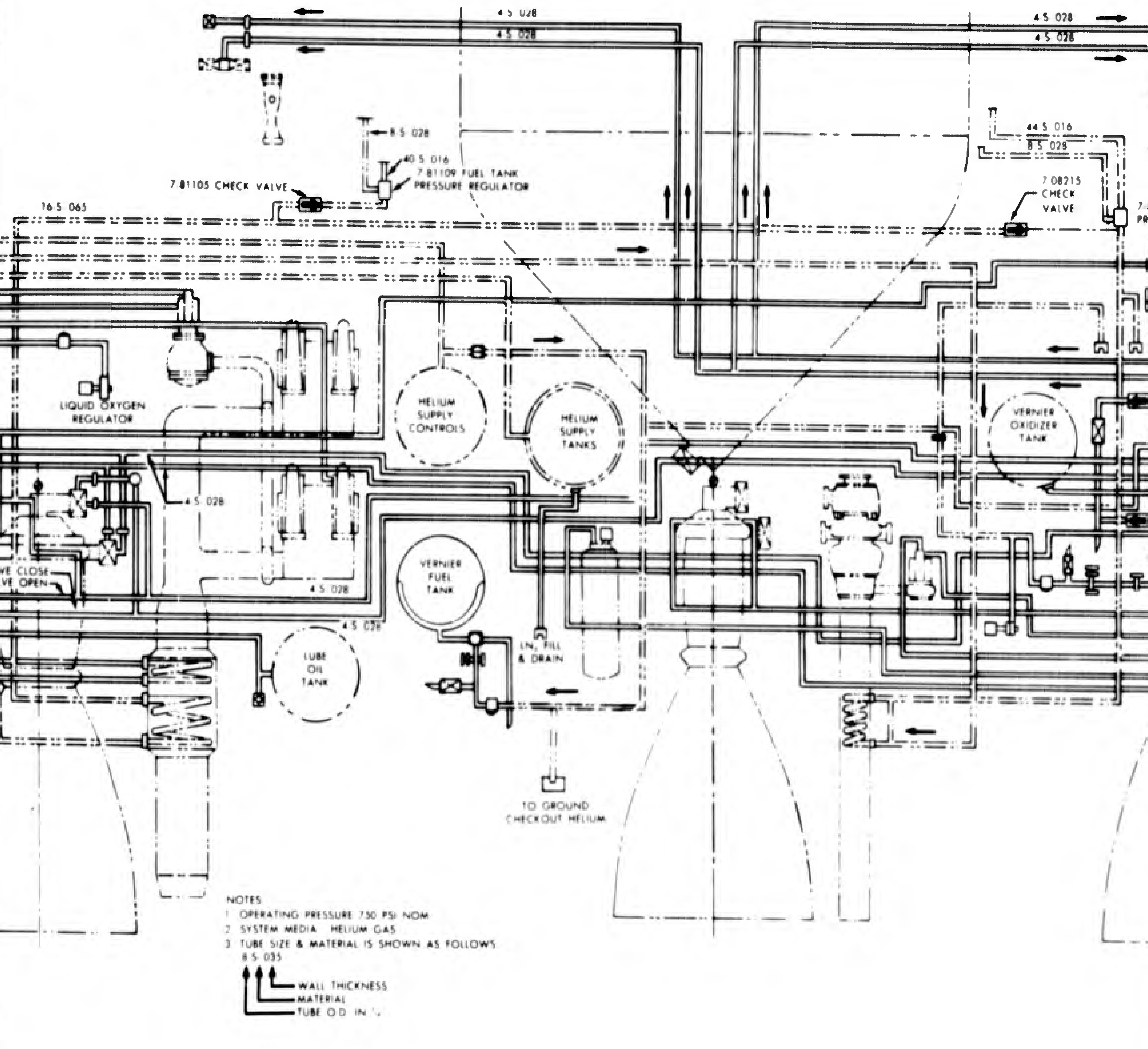


Figure 27. Helium Syster

B.

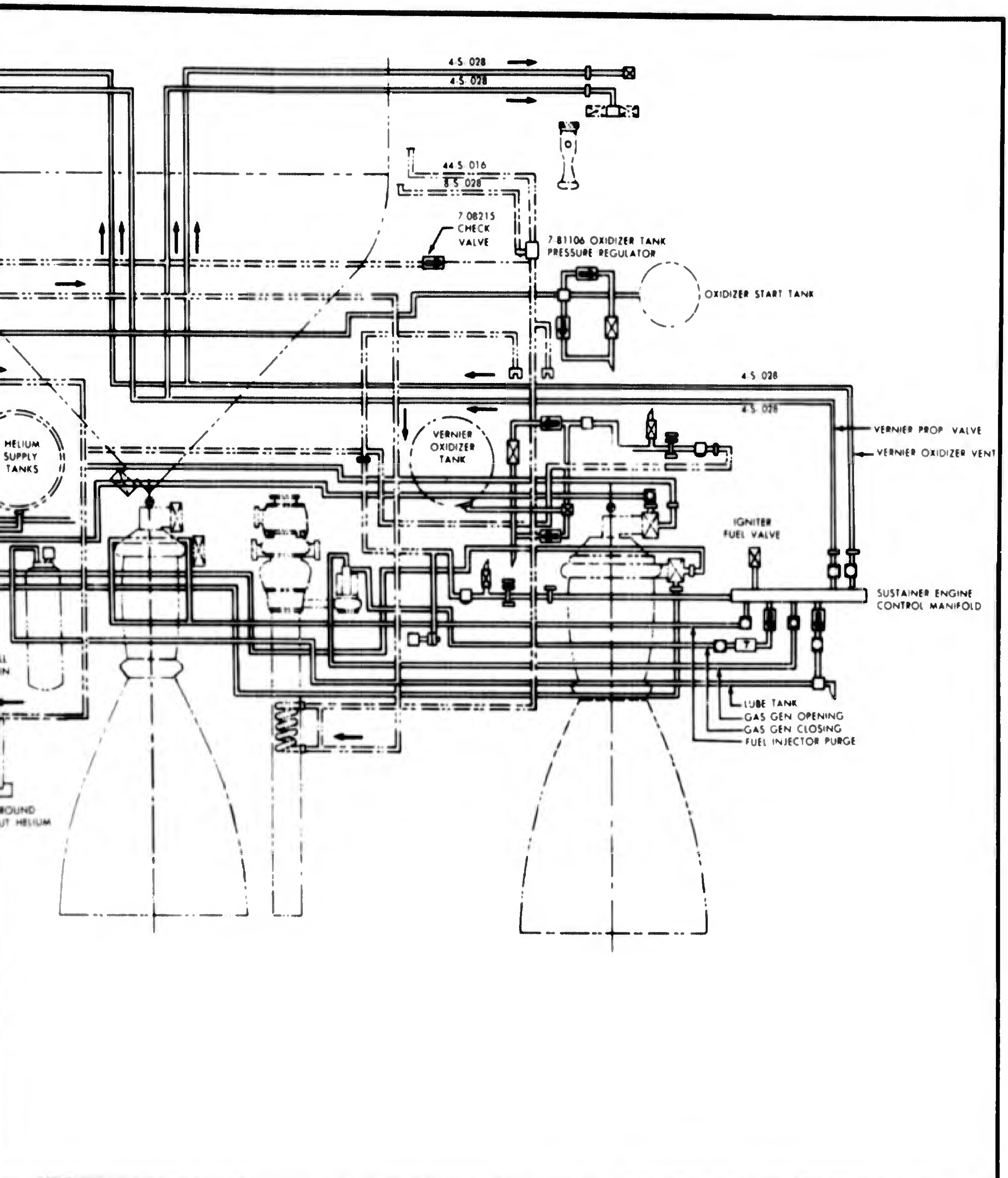


Figure 27. Helium System Engine Controls Schematic

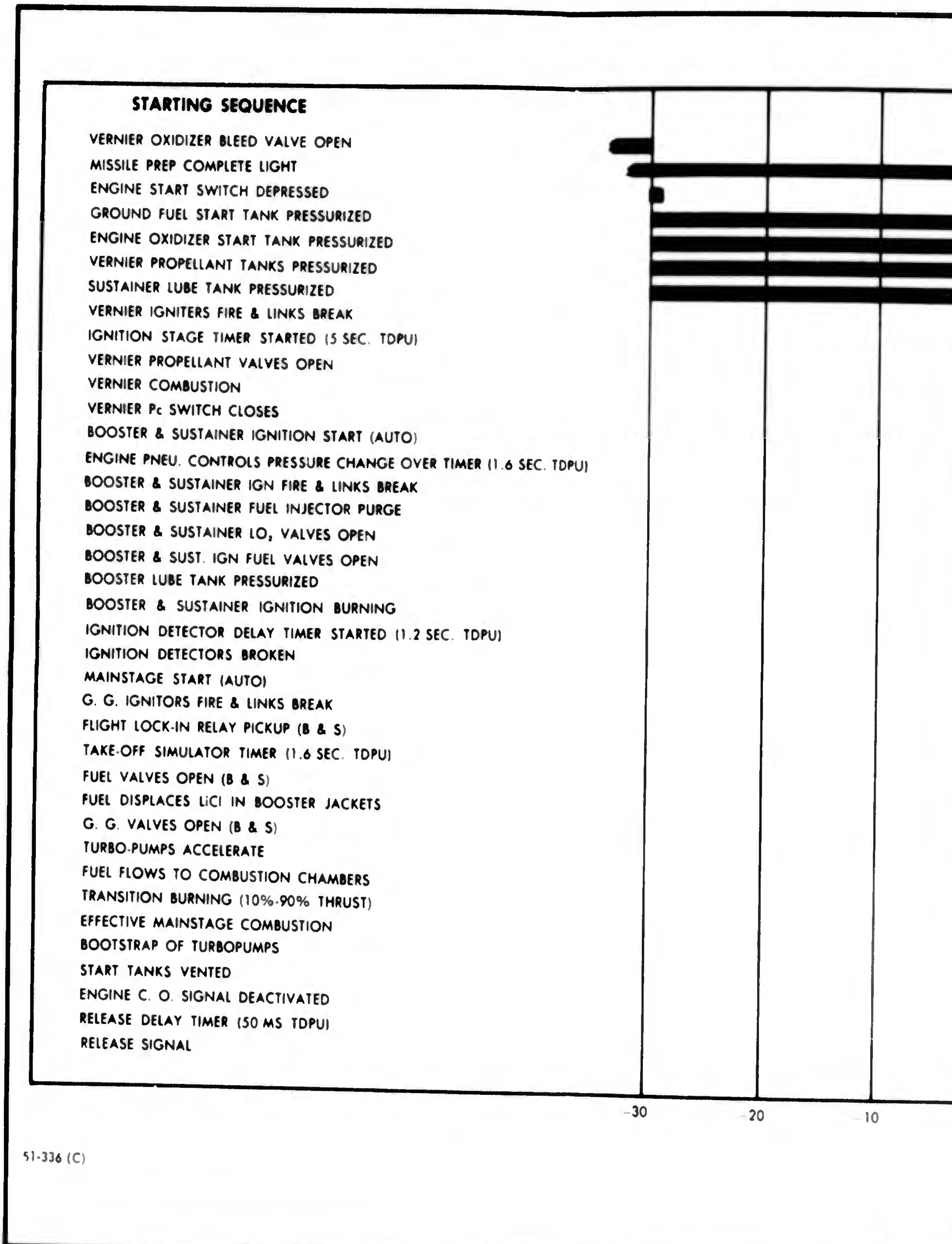

STARTING SEQUENCE
VERNIER OXIDIZER BLEED VALVE OPEN
MISSILE PREP COMPLETE LIGHT
ENGINE START SWITCH DEPRESSED
GROUND FUEL START TANK PRESSURIZED
ENGINE OXIDIZER START TANK PRESSURIZED
VERNIER PROPELLANT TANKS PRESSURIZED
SUSTAINER LUBE TANK PRESSURIZED
VERNIER IGNITERS FIRE & LINKS BREAK
IGNITION STAGE TIMER STARTED (5 SEC. TDPU)
VERNIER PROPELLANT VALVES OPEN
VERNIER COMBUSTION
VERNIER Pc SWITCH CLOSES
BOOSTER & SUSTAINER IGNITION START (AUTO)
ENGINE PNEU. CONTROLS PRESSURE CHANGE OVER TIMER (1.6 SEC. TDPU)
BOOSTER & SUSTAINER IGN FIRE & LINKS BREAK
BOOSTER & SUSTAINER FUEL INJECTOR PURGE
BOOSTER & SUSTAINER LO2 VALVES OPEN
BOOSTER & SUST. IGN FUEL VALVES OPEN
BOOSTER LUBE TANK PRESSURIZED
BOOSTER & SUSTAINER IGNITION BURNING
IGNITION DETECTOR DELAY TIMER STARTED (1.2 SEC. TDPU)
IGNITION DETECTORS BROKEN
MAINSTAGE START (AUTO)
G. G. IGNITORS FIRE & LINKS BREAK
FLIGHT LOCK-IN RELAY PICKUP (B & S)
TAKE-OFF SIMULATOR TIMER (1.6 SEC. TDPU)
FUEL VALVES OPEN (B & S)
FUEL DISPLACES LiCl IN BOOSTER JACKETS
G. G. VALVES OPEN (B & S)
TURBO-PUMPS ACCELERATE
FUEL FLOWS TO COMBUSTION CHAMBERS
TRANSITION BURNING (10%-90% THRUST)
EFFECTIVE MAINSTAGE COMBUSTION
BOOTSTRAP OF TURBOPUMPS
START TANKS VENTED
ENGINE C. O. SIGNAL DEACTIVATED
RELEASE DELAY TIMER (50 MS TDPU)
RELEASE SIGNAL
-30
-20
-10
51-336 (C)

Figure 28

A.

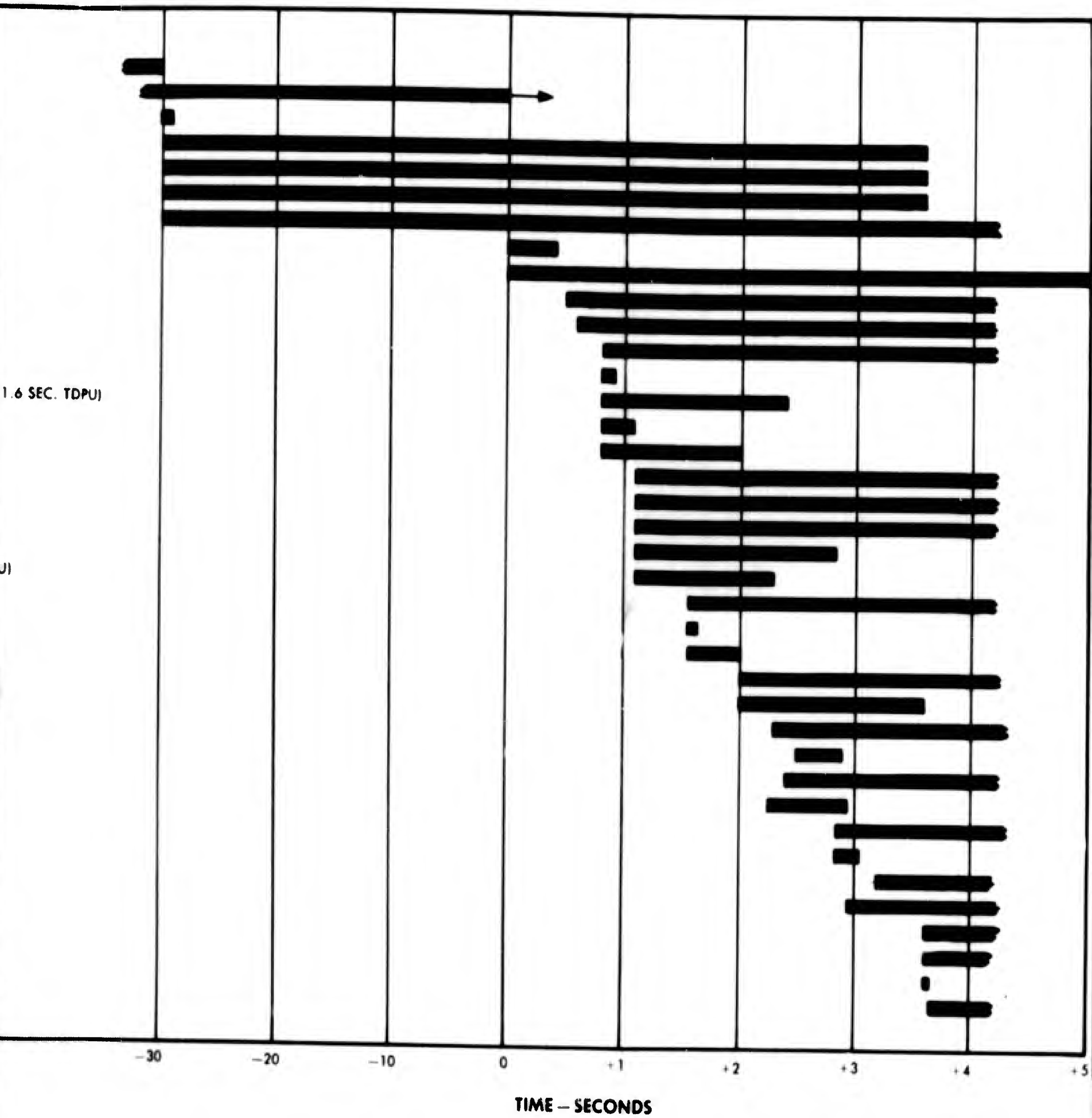


Figure 28. Engine Start and Shutdown Sequence

B.

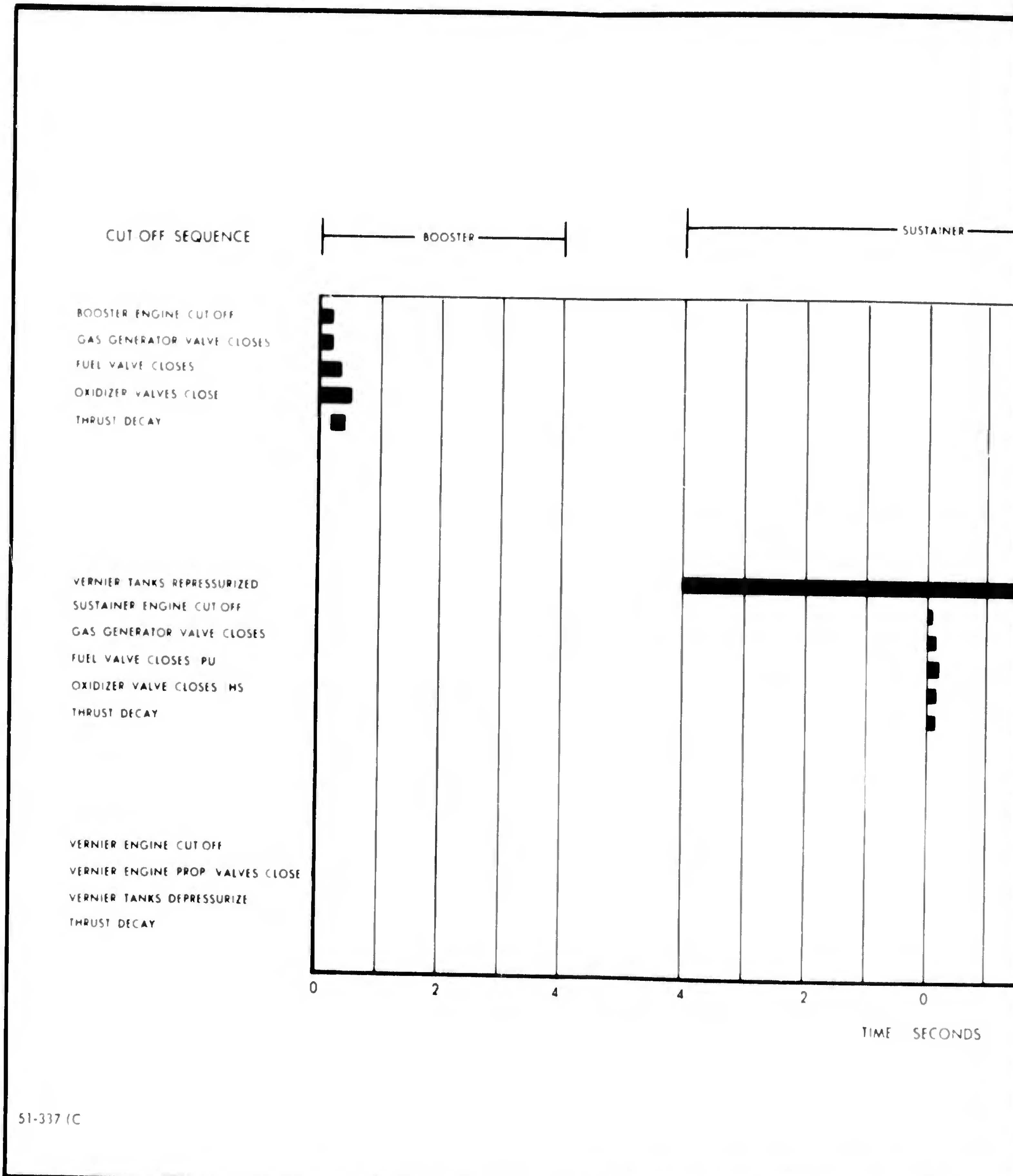

CUT OFF SEQUENCE
BOOSTER
SUSTAINER
BOOSTER ENGINE CUT OFF
GAS GENERATOR VALVE CLOSES
FUEL VALVE CLOSES
OXIDIZER VALVES CLOSE
THRUST DECAY
VERNIER TANKS REPRESSURIZED
SUSTAINER ENGINE CUT OFF
GAS GENERATOR VALVE CLOSES
FUEL VALVE CLOSES PU
OXIDIZER VALVE CLOSES HS
THRUST DECAY
VERNIER ENGINE CUT OFF
VERNIER ENGINE PROP VALVES CLOSE
VERNIER TANKS DEPRESSURIZE
THRUST DECAY
0
2
4
4
2
0
TIME SECONDS
51-337 (C

Figure 29.

A.

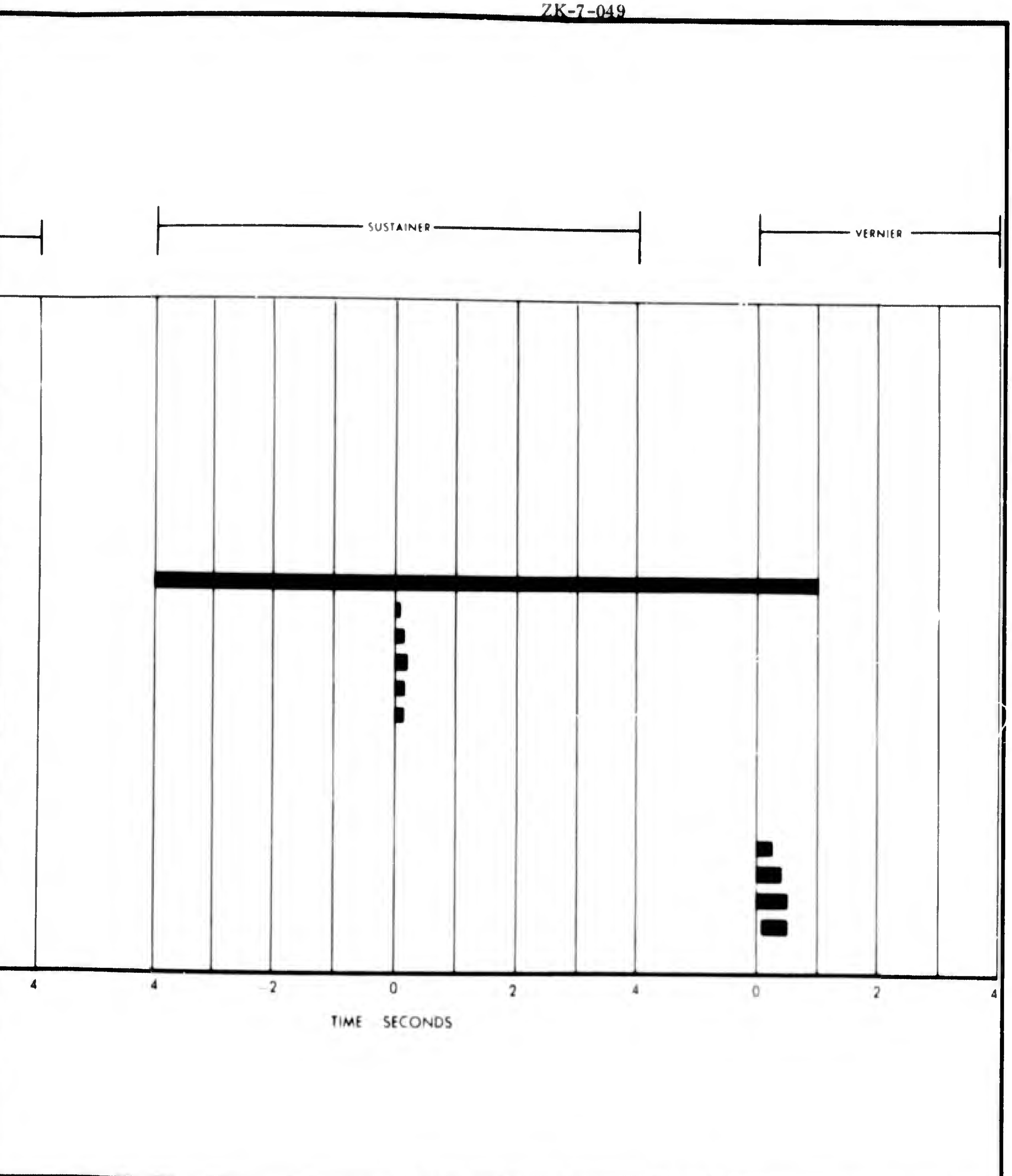
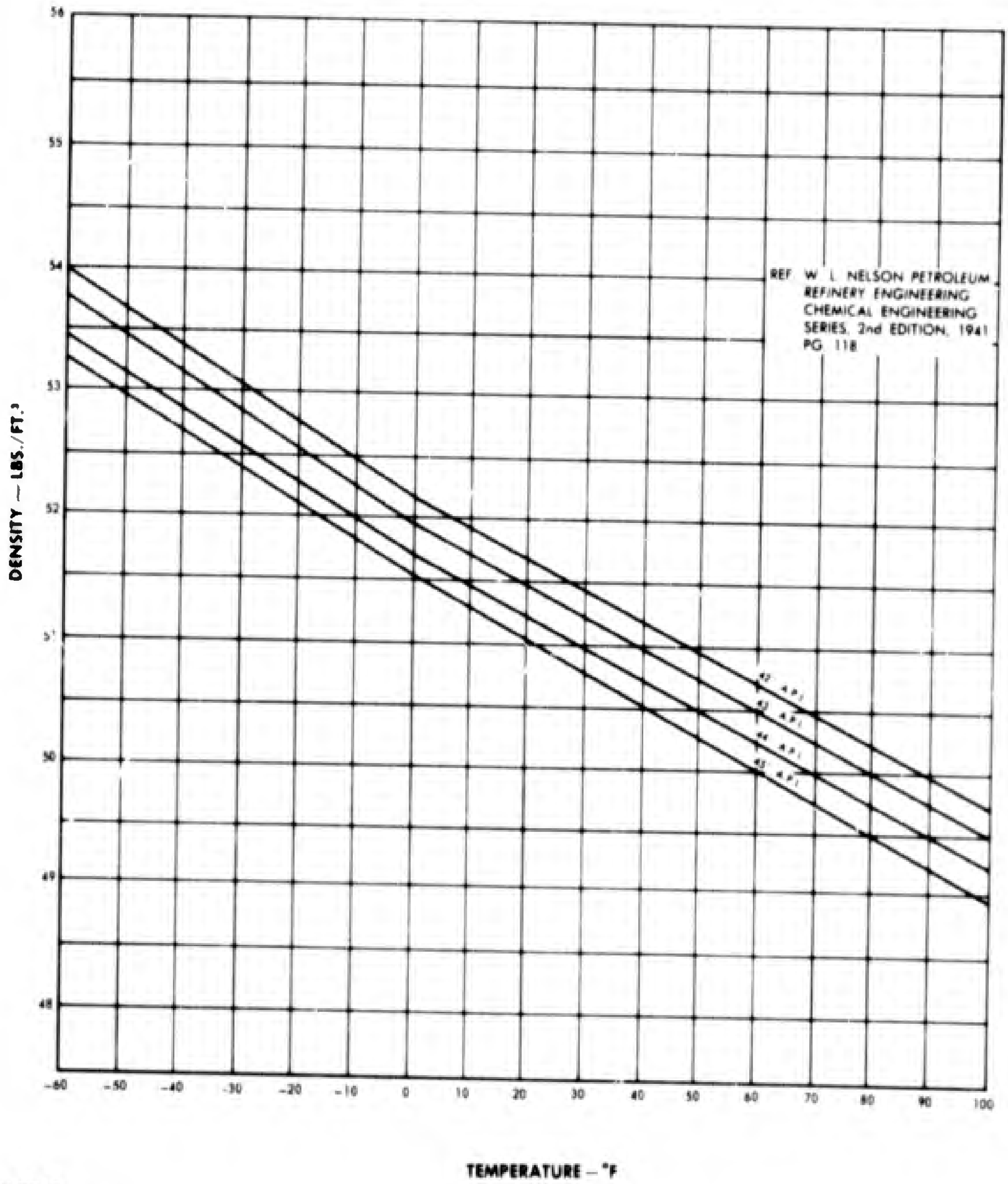
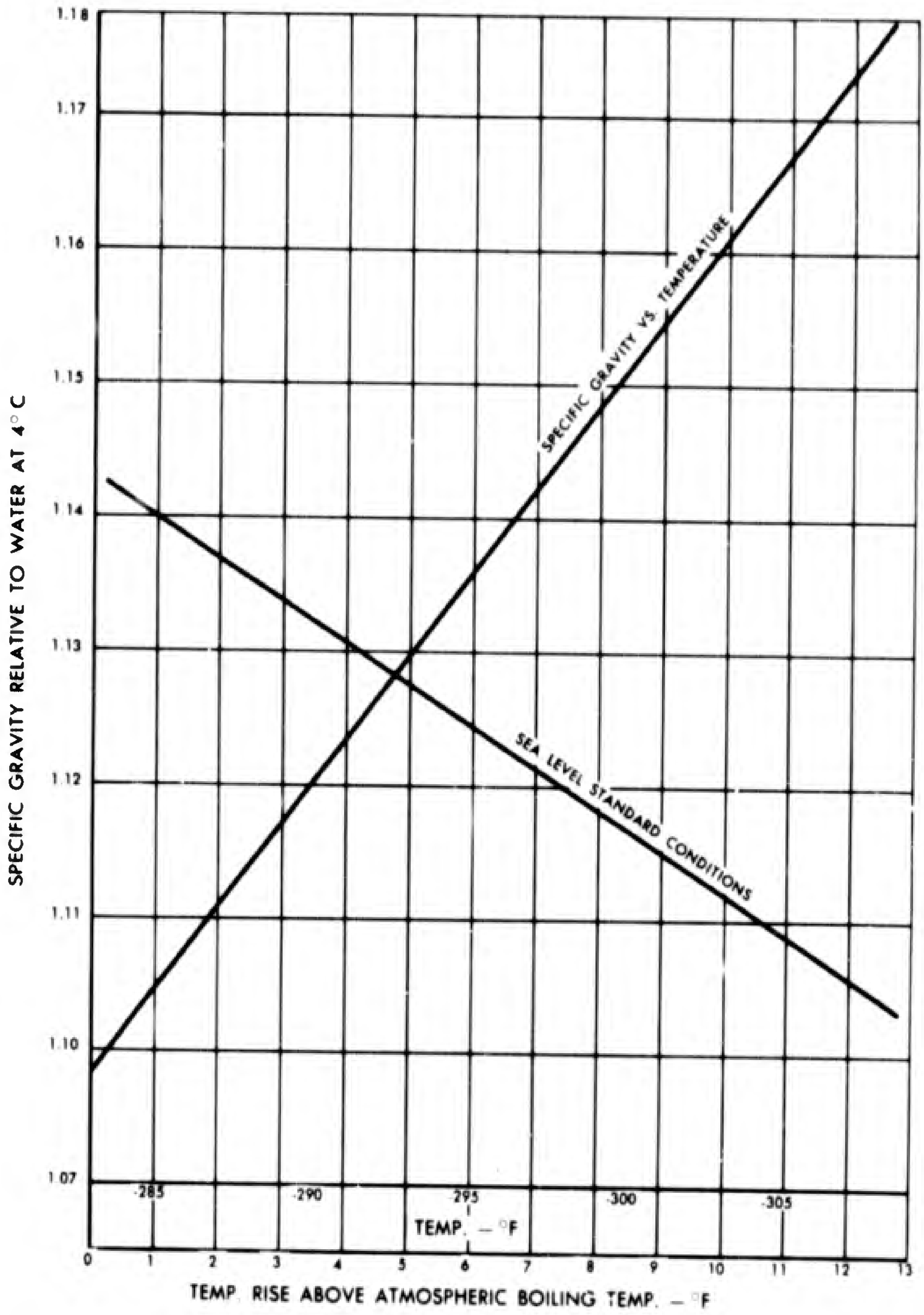


Figure 29. Engine Sequence Block Diagram



51-338 (C)

Figure A-1. Change of Density with Temperature for Petroleum Oil with API Gravities of 42, 43, 44 and 45



51-339 (C)

Figure A-2. Specific Gravity of Liquid Oxygen vs. Temperature

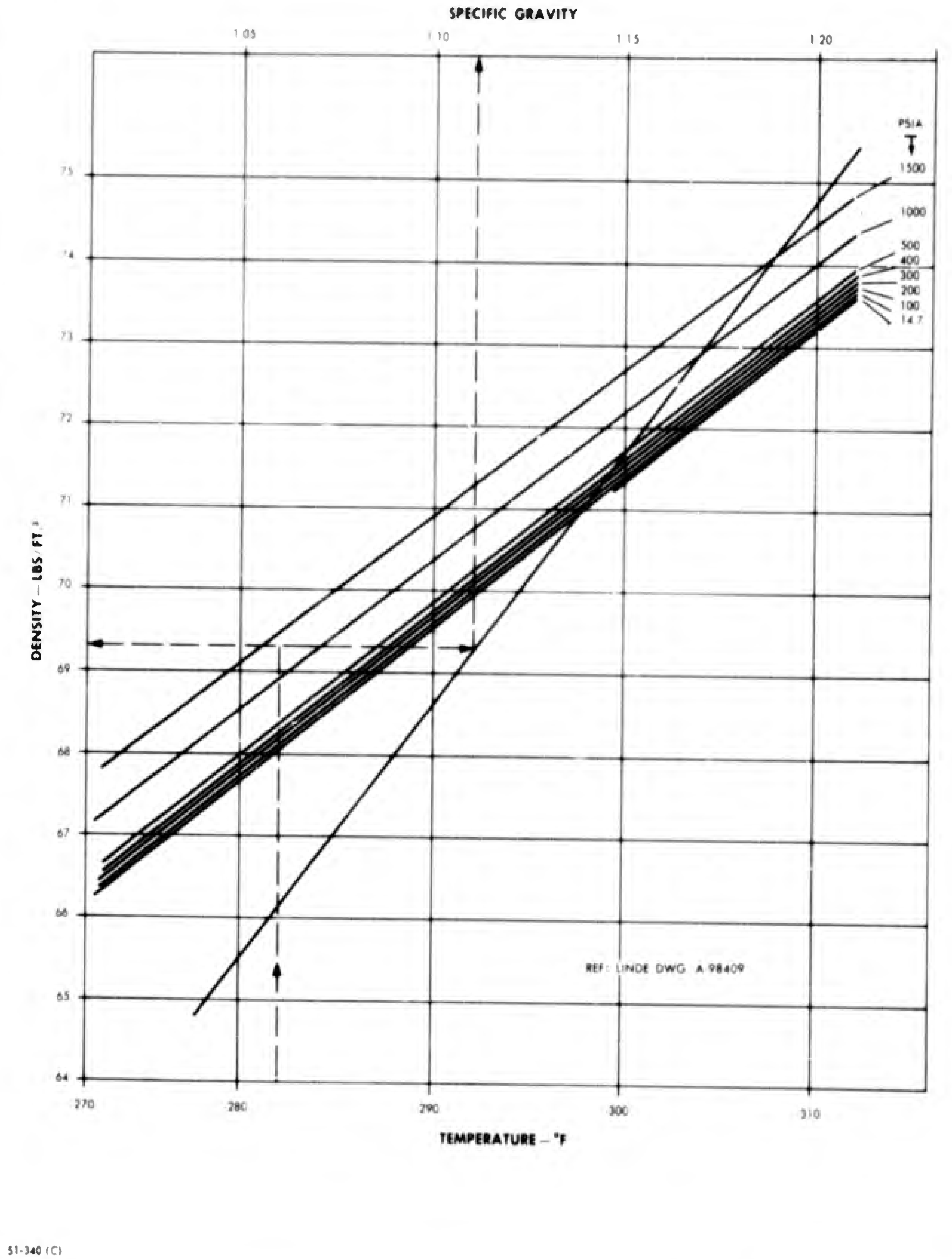


Figure A-3. Liquid Oxygen Density vs. Temperature

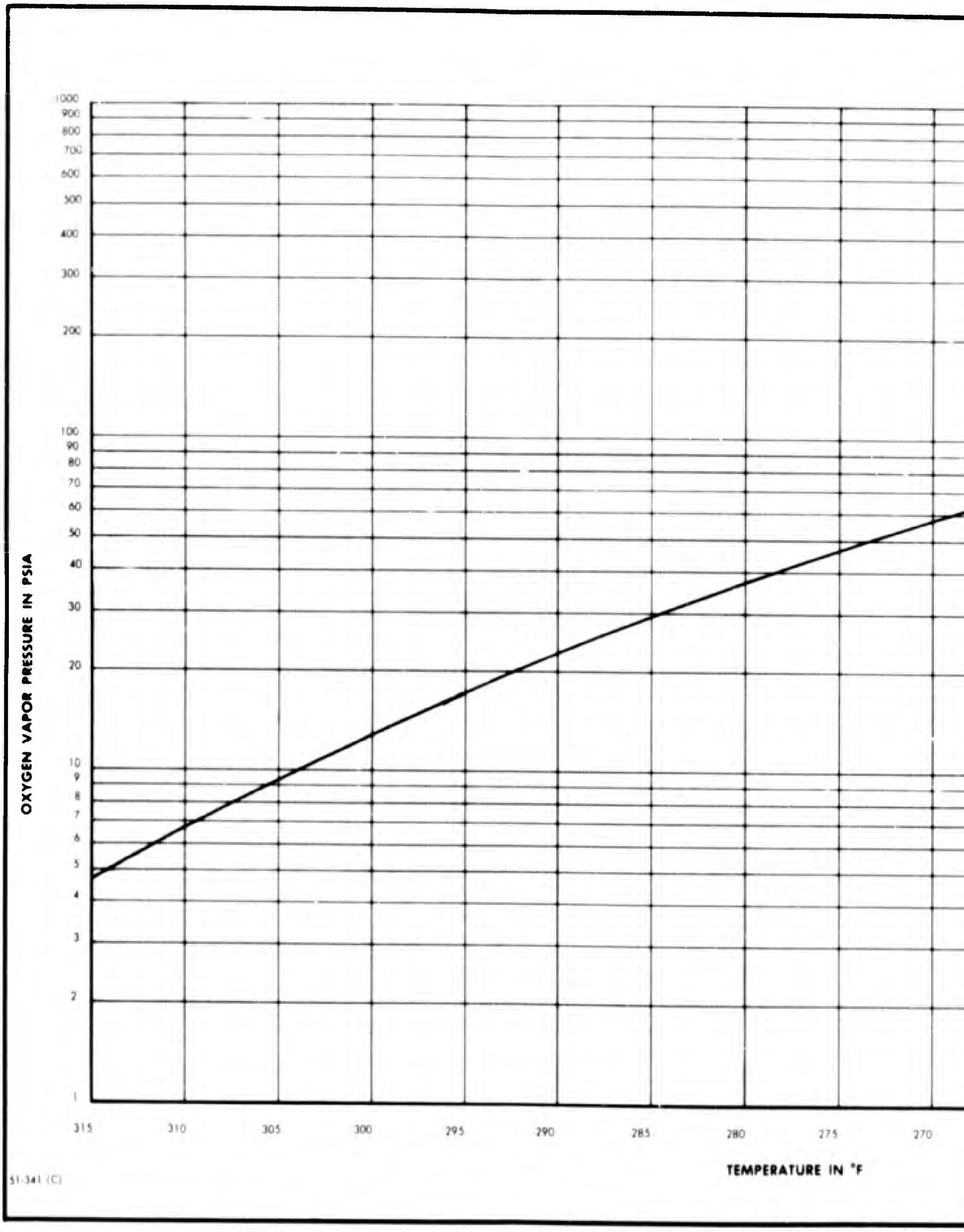


Figure A-4. Vapor

A.

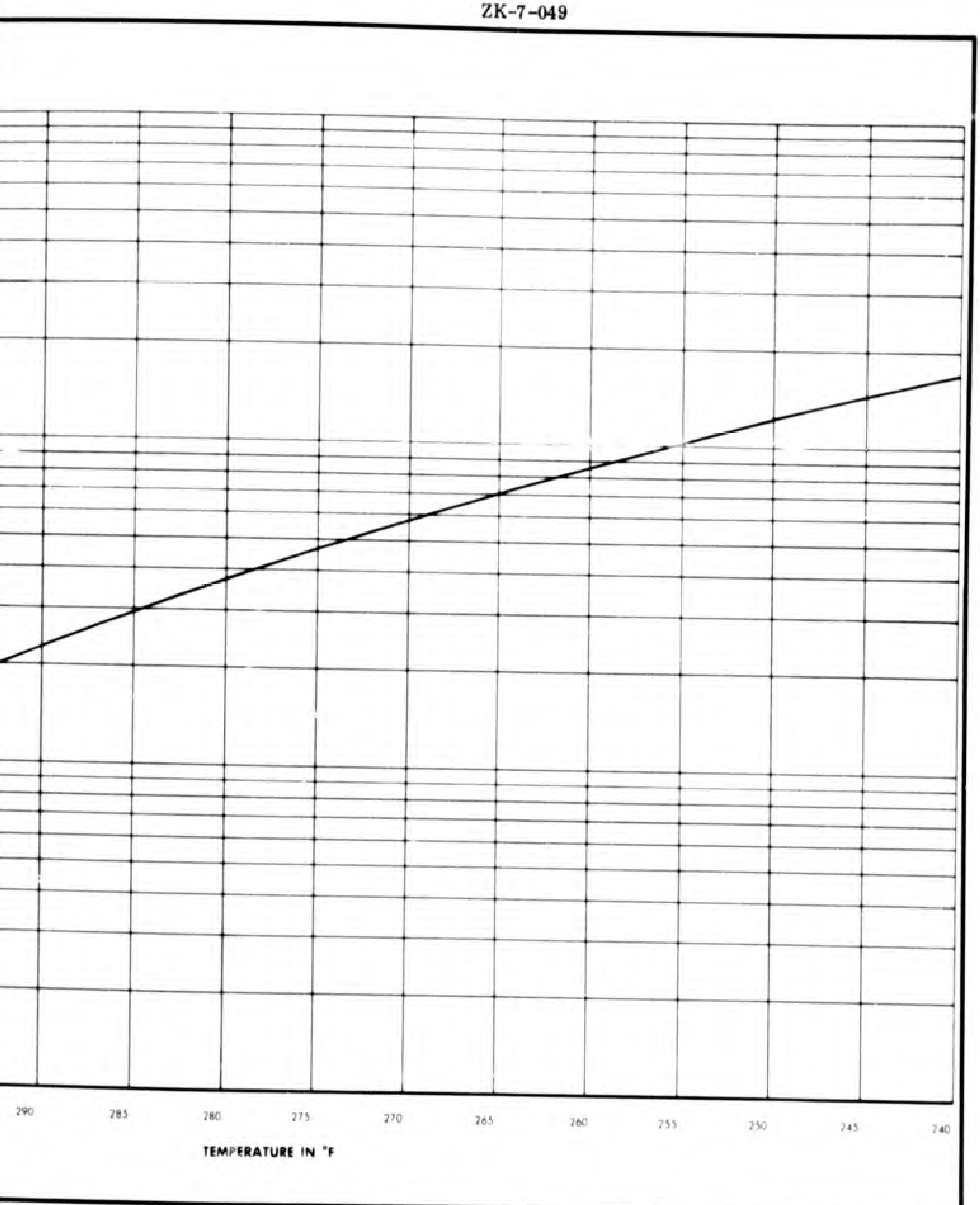
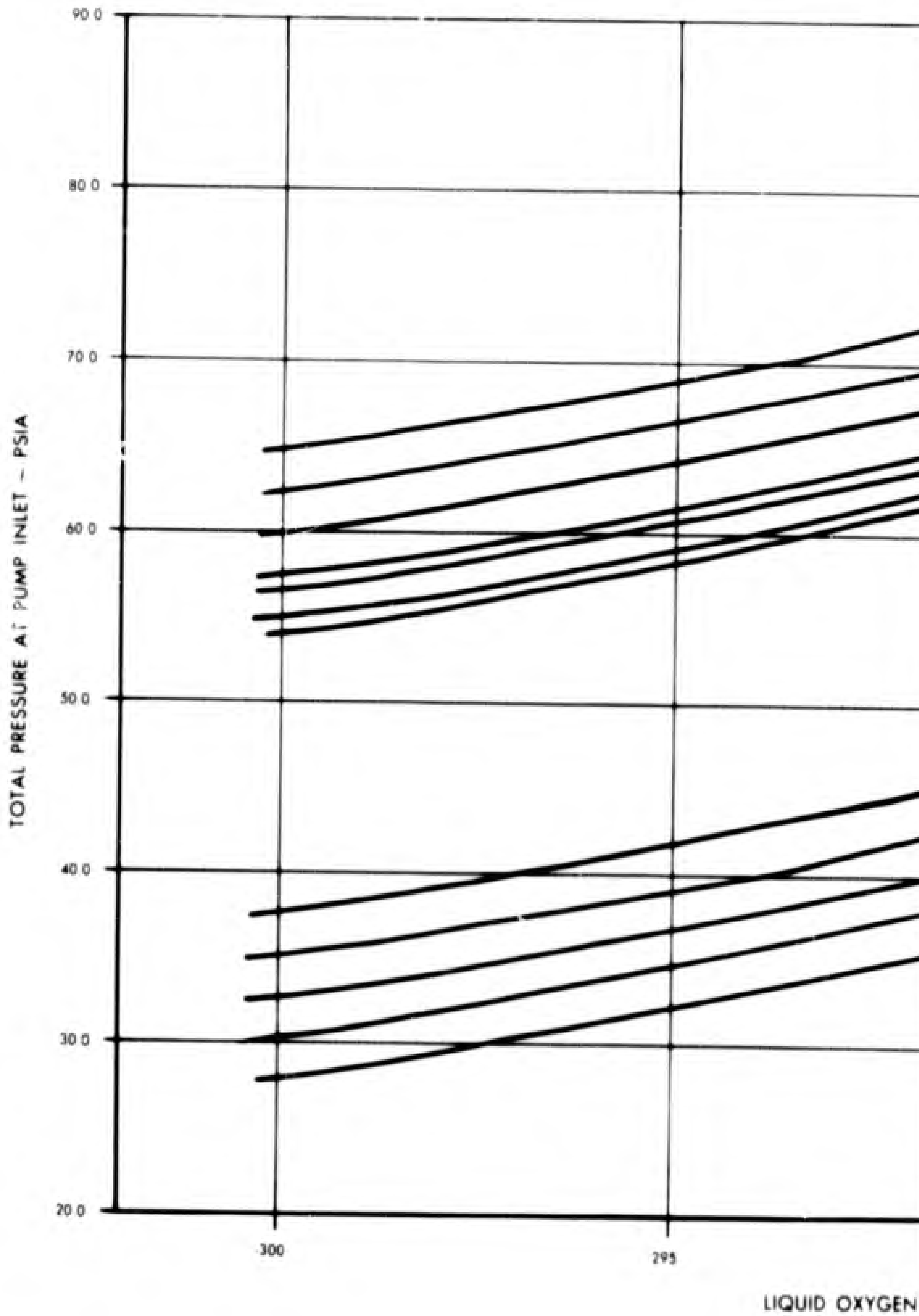


Figure A-4. Vapor Pressure of Oxygen vs. Temperature


90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
TOTAL PRESSURE AT PUMP INLET – PSIA
-300
295
LIQUID OXYGEN

51-342 (C)

A.

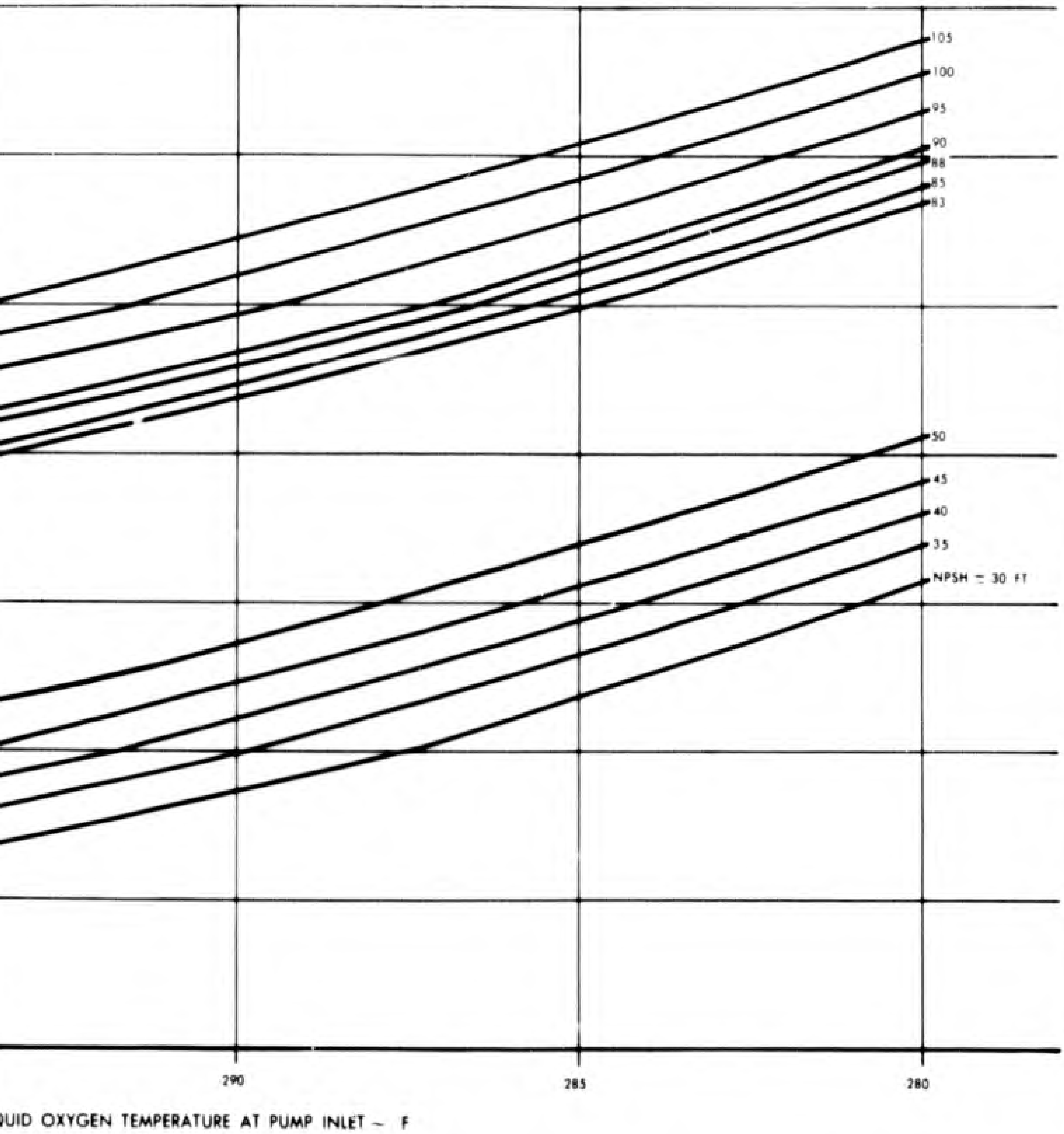
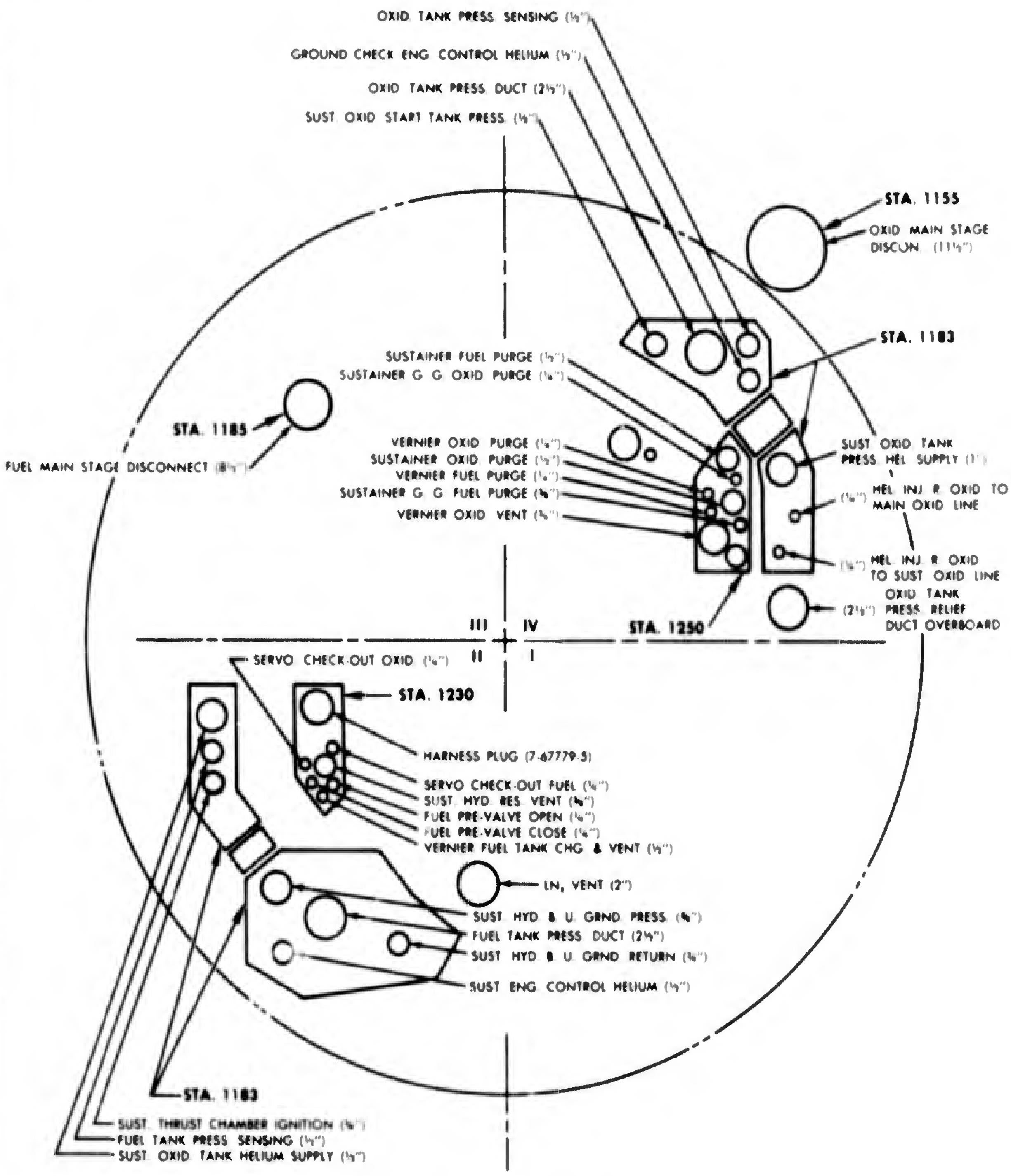


Figure A-5. Liquid Oxygen Pump Total Inlet Pressure vs. Inlet Temperature

B.

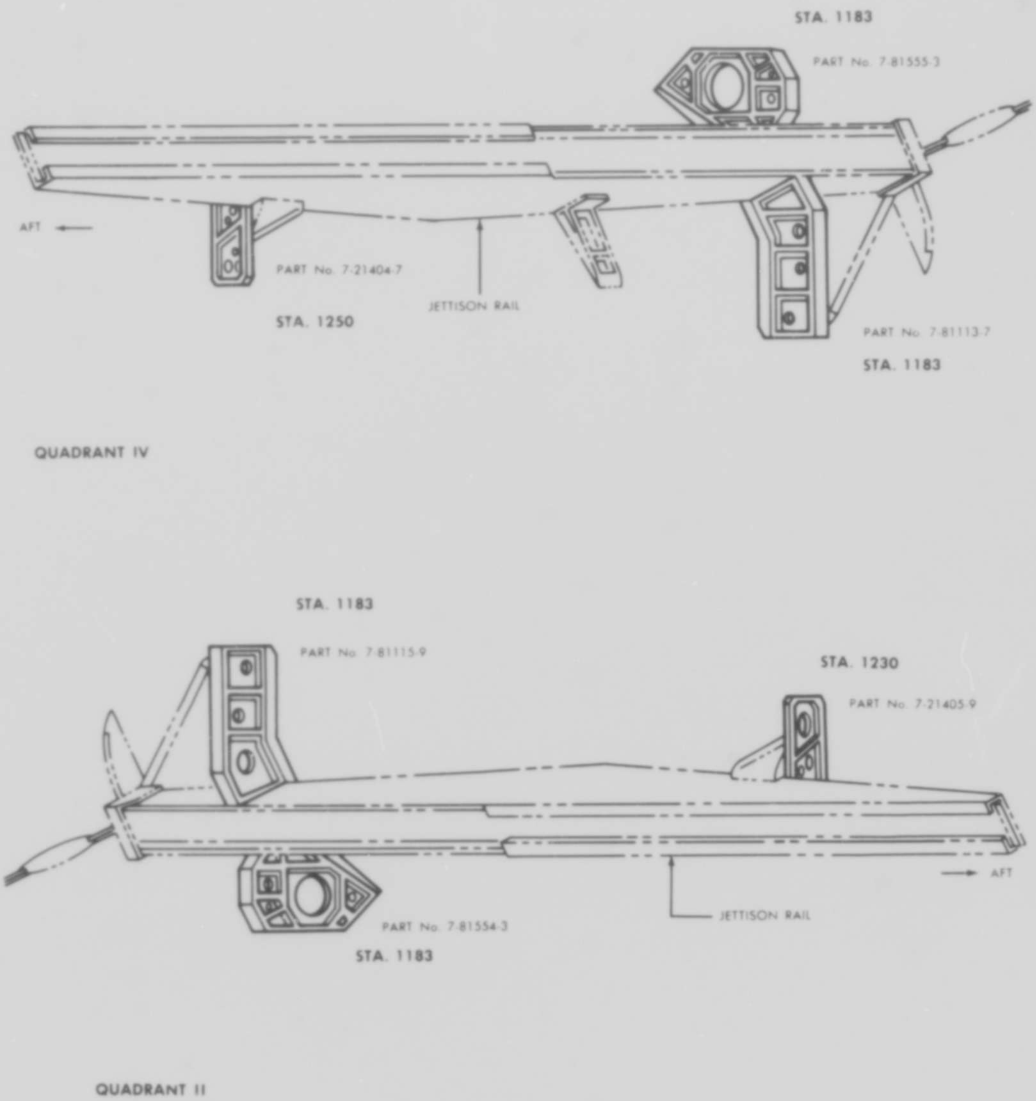


NOTE: (0/0") INDICATES TUBE SIZES WHICH ATTACH TO DISCONNECT

a. VIEW OF AFT END OF MISSILE TANKS SHOWING LOCATION OF DISCONNECTS.

51-343 (C)

Figure A-6. View of Aft End of Missile Tanks Showing Location of Disconnects



b. VIEW OF JETTISON RAILS SHOWING LOCATION OF DISCONNECT PANELS

51-344 (C)

Figure A-7. View of Jettison Rails Showing Location of Disconnect Panels

APPENDIX

TABLE I. PROPERTIES OF LIQUID OXYGEN

Boiling point at 1 atm	=	-297.35°F (-182.97°C)
Critical temperature	=	-181.88°F (-118.82°C)
Critical pressure	=	715.6 psig
*Density (liquid)	=	71.27 lb/ft^3
*Density (gas)	=	.08270 lb/ft^3
Cubic foot of gas per cubic foot of liquid	=	862
Cubic foot of gas per gallon of liquid	=	115.2
Weight of gallon of liquid	=	9.53
Specific volume of NTP	=	12.1 ft^3/lb
Heat content of saturated vapor	=	1788 gm cal/mole
Heat of vaporazation at 1 atm	=	1630 gm cal/mole
Molecular weight	=	32.0
Gallon per ft^3	=	8.3
Specific gravity	=	1.14 @ 183°C
1 cubic foot of gaseous oxygen	=	.00868 gal liquid oxygen
	=	.0827 lb liquid oxygen
	=	28.32 liter 0_2
1 liter of liquid oxygen	=	2.52 lb liquid oxygen
	=	1.05 qt liquid oxygen
	=	.264 gal liquid oxygen
	=	30.44 ft^3 0_2
1 pound of liquid oxygen	=	12.1 ft^3 0_2
	=	.105 gal liquid oxygen
1 gallon of liquid oxygen	=	115.23 ft^3 0_2
	=	9.53 lb liquid oxygen

*Boiling point at 1 atm.

NOTE: Information in table was obtained from Linde Air Products.